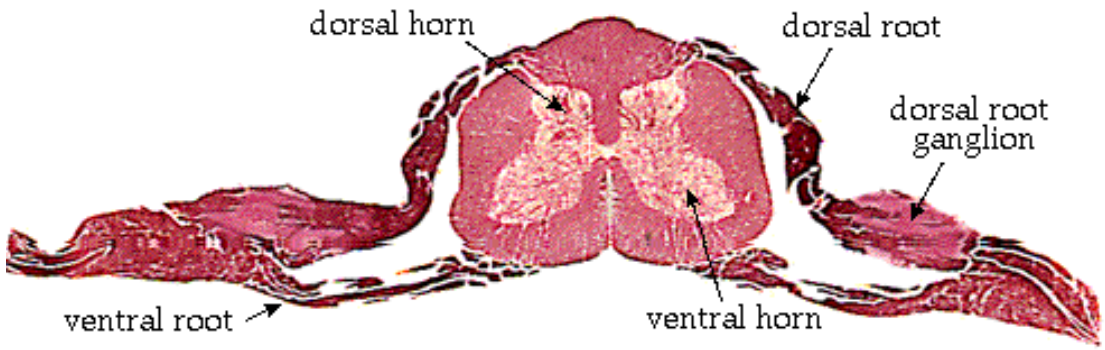
Spinal Cord

Neurons of the Cord

- Afferent neurons
  - sensory
  - located outside of the cord (dorsal root ganglia)
  - receive information from the sensory receptors and sends that information toward the CNS
- Efferent neurons
  - motor neurons
  - located in ventral horn
  - receives info form the CNS and sends it to the muscles
- Interneurons
  - connects afferent pathways to efferent
  - sends info to brain
  - are involved in reflex arc

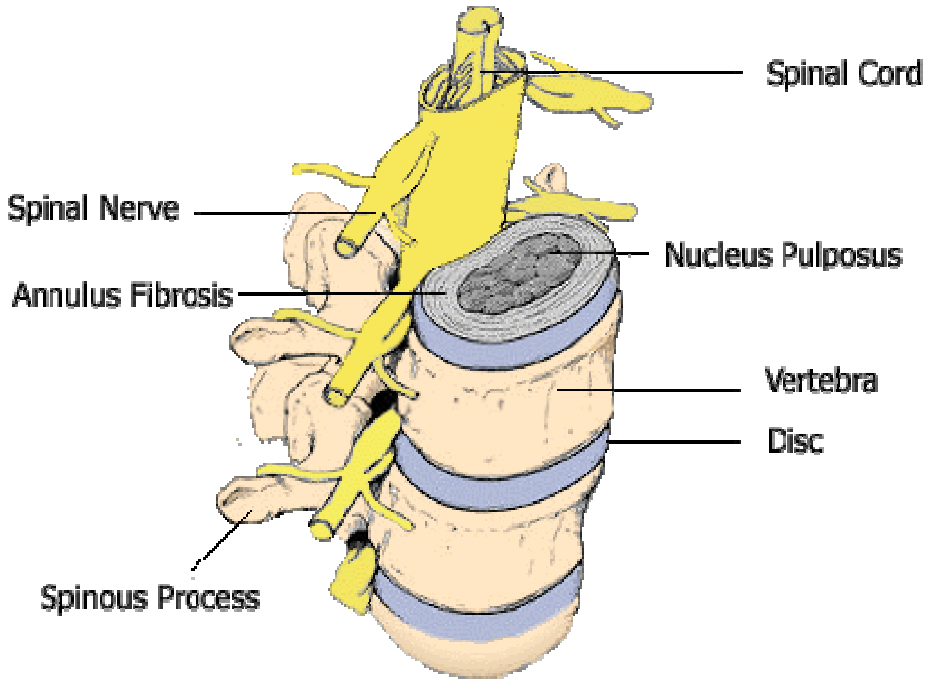
Spinal Cord Organization

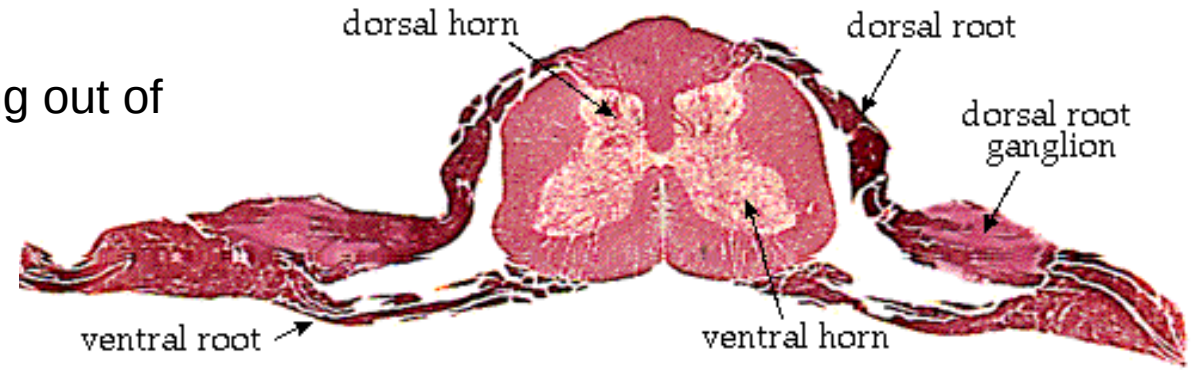
- **Gray matter**: mostly cell bodies
  - Dendrites & terminals
  - Spinal reflex integrating center
- **White matter**
  - Bundles of myelinated axons
    - Ascending tracts – sensory
    - Descending tracts – motor
- the cord can be divided into segments by the nerve roots that come off of it



Spinal Cord Organization

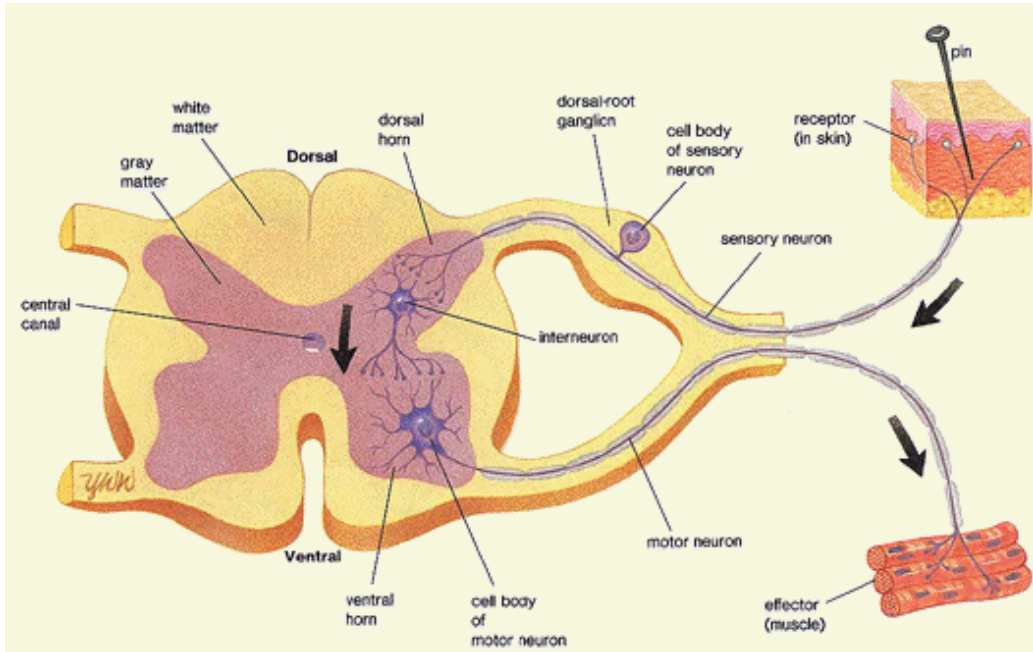
- although the rootlets branch off nearly continuously, they coalesce into about 31 discrete nerves along the cord (8 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 1 coccygeal nerves).
- At each segment, rootlets appear to come out of both the dorsal and ventral halves of the spinal cord,
  - Dorsal roots- going into the cord
  - Ventral roots- coming out of the of the cord



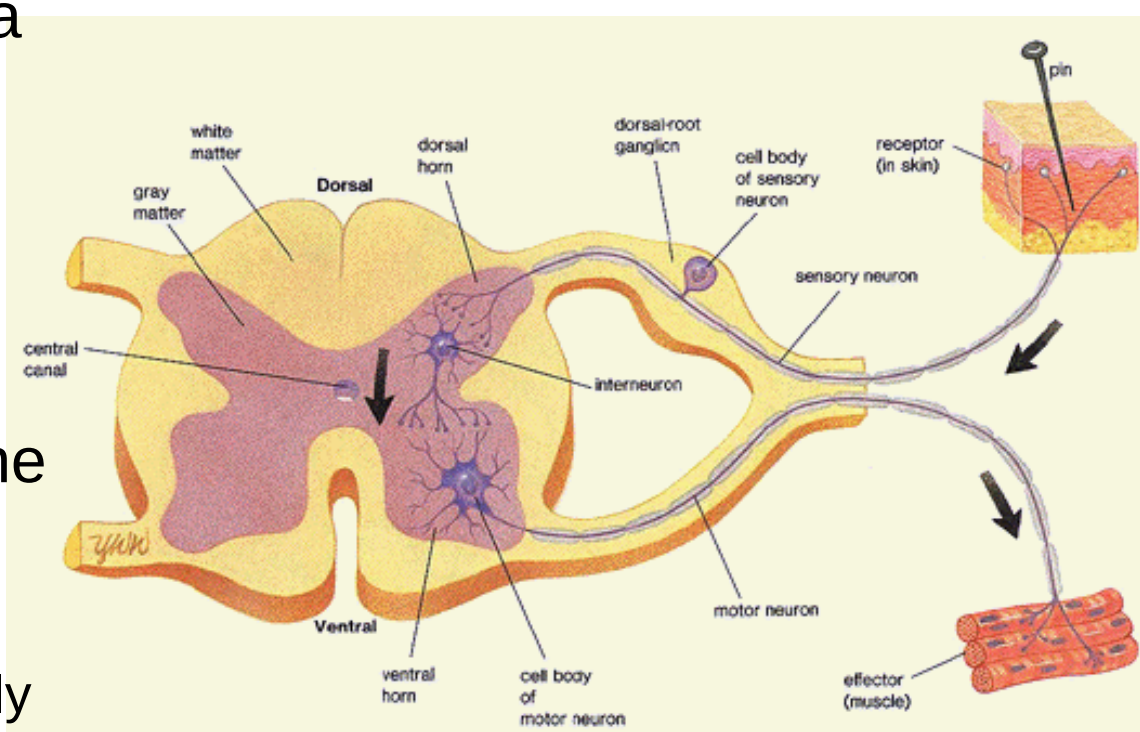


Spinal Cord Organization

- **Posterior (dorsal) horn**
  - contains somatic and visceral sensory nuclei
  - deals with sensory perception, and receives information from the periphery through the dorsal root.
- **Anterior (ventral) horn** deals with somatic motor control
  - contain the **a-motor neurons**, whose axons exit the cord via the ventral roots and travel directly to the muscles.
- **Lateral horn** contains visceral motor neurons
- Gray commissures contain axons that cross from one side to the other

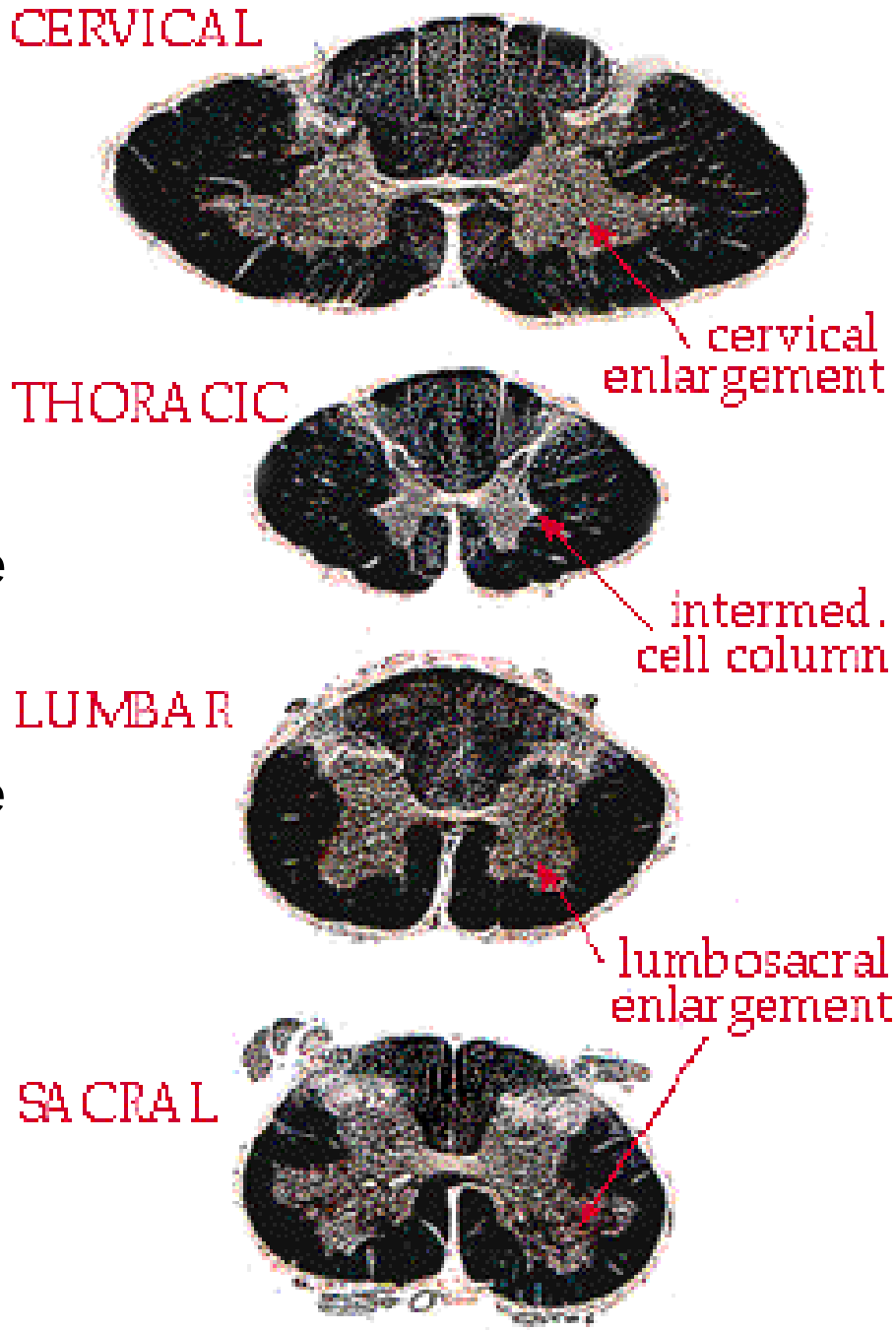


- Along the dorsal root is a collection of cell bodies called the **dorsal root ganglion**.
- Inside the ganglion are the cell bodies of all the receptor neurons that send processes out to the periphery.
  - The free nerve ending in the tip of your finger that feels the paper cut actually has its cell body back in the dorsal root ganglion.



Differentiating Levels of the Cord

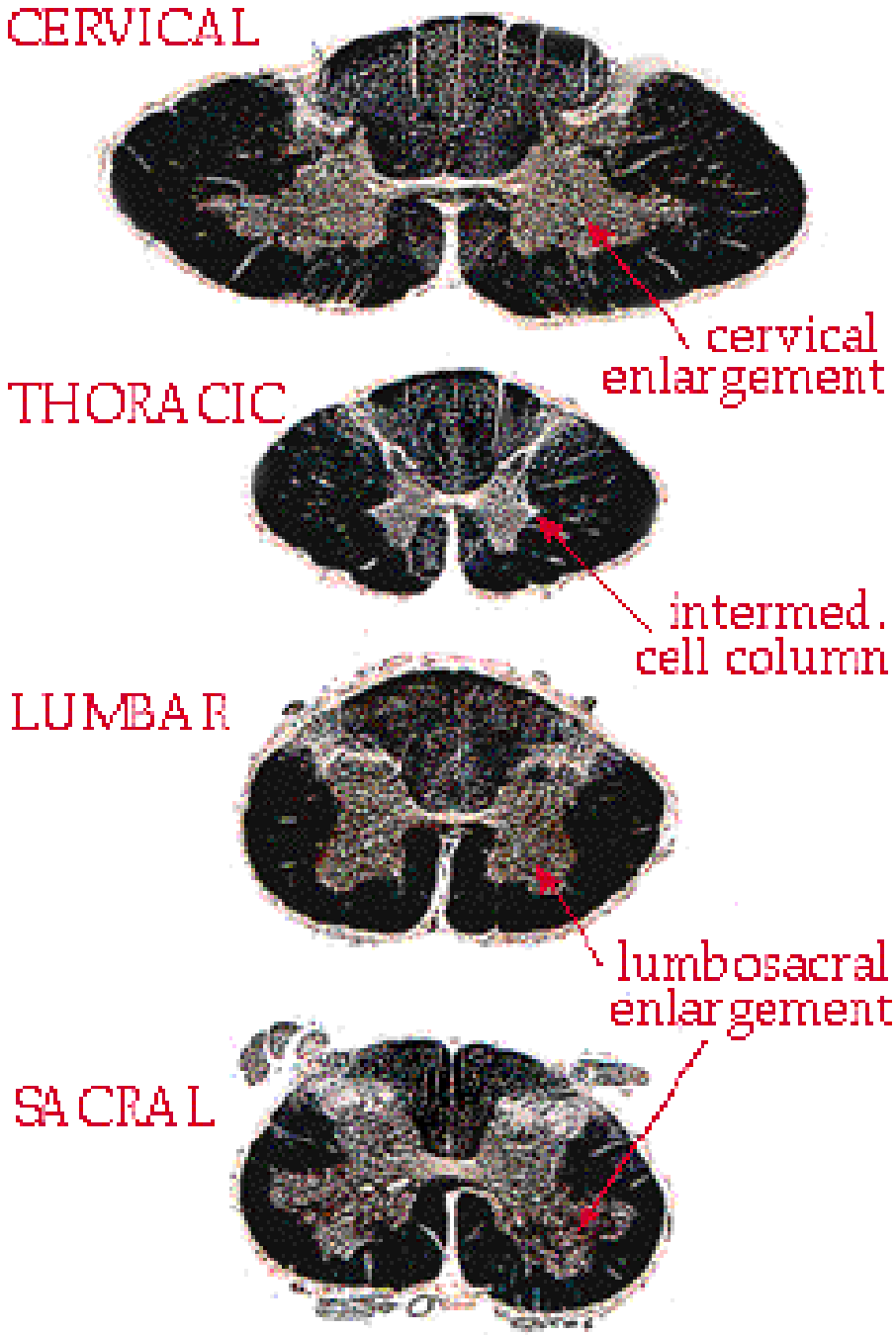
- Overall shape
  - Cervical sections tend to be wide and squashed looking, like an oval.
  - Compare the cervical section to the round lumbar section.
- <u>ventral horn enlargement</u>-
  - At segments that control a limb, the motor neurons are large and numerous.
  - This causes enlarged ventral horns in two places: the lower cervical sections (C5-C8) and the lumbar/sacral sections.



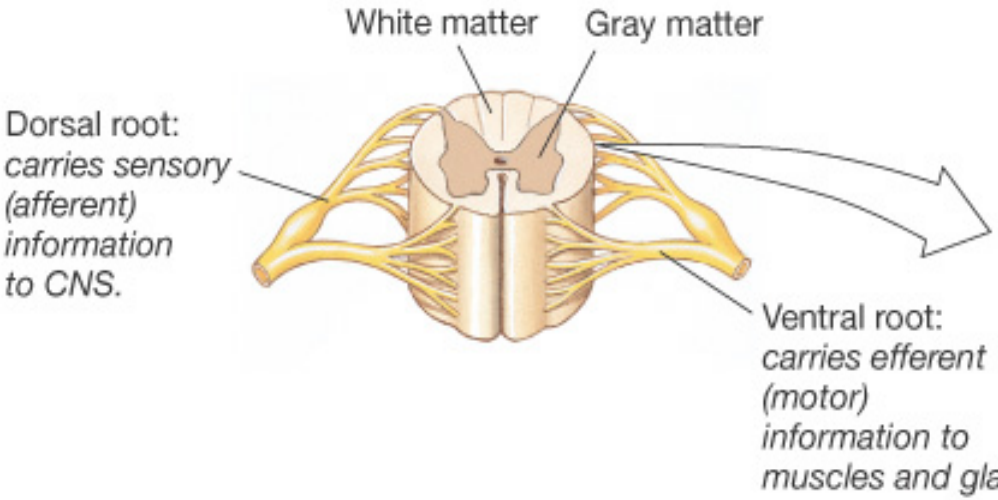
Differentiating Levels of the Cord

Proportion of white matter to gray matter

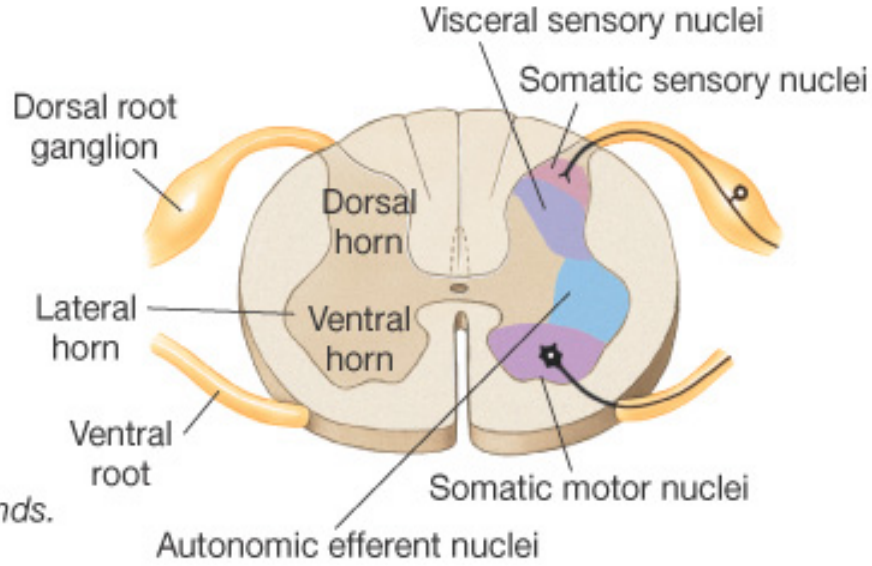
- The amount of white matter relative to grey matter decreases as you move down the cord.
  - in the white matter of the cervical cord you have all of the axons going to or from the entire body, more or less. In sacral cord the white matter contains only those axons going to or from the last couple of dermatomes - all other axons have "gotten off" at higher levels.



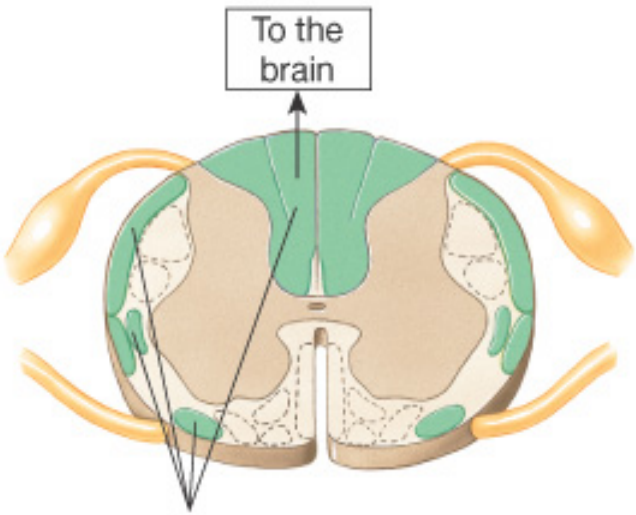
(a) One segment of spinal cord, ventral view, showing its pair of nerves.



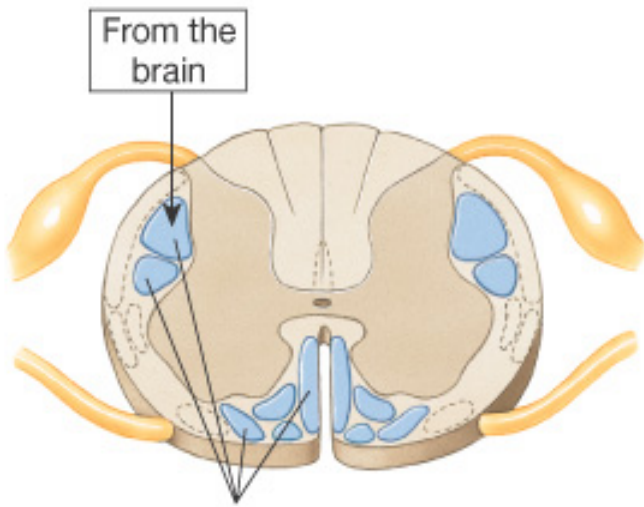
(b) Gray matter consists of sensory and motor nuclei.



(c) White matter in the spinal cord consists of axons carrying information to and from the brain.



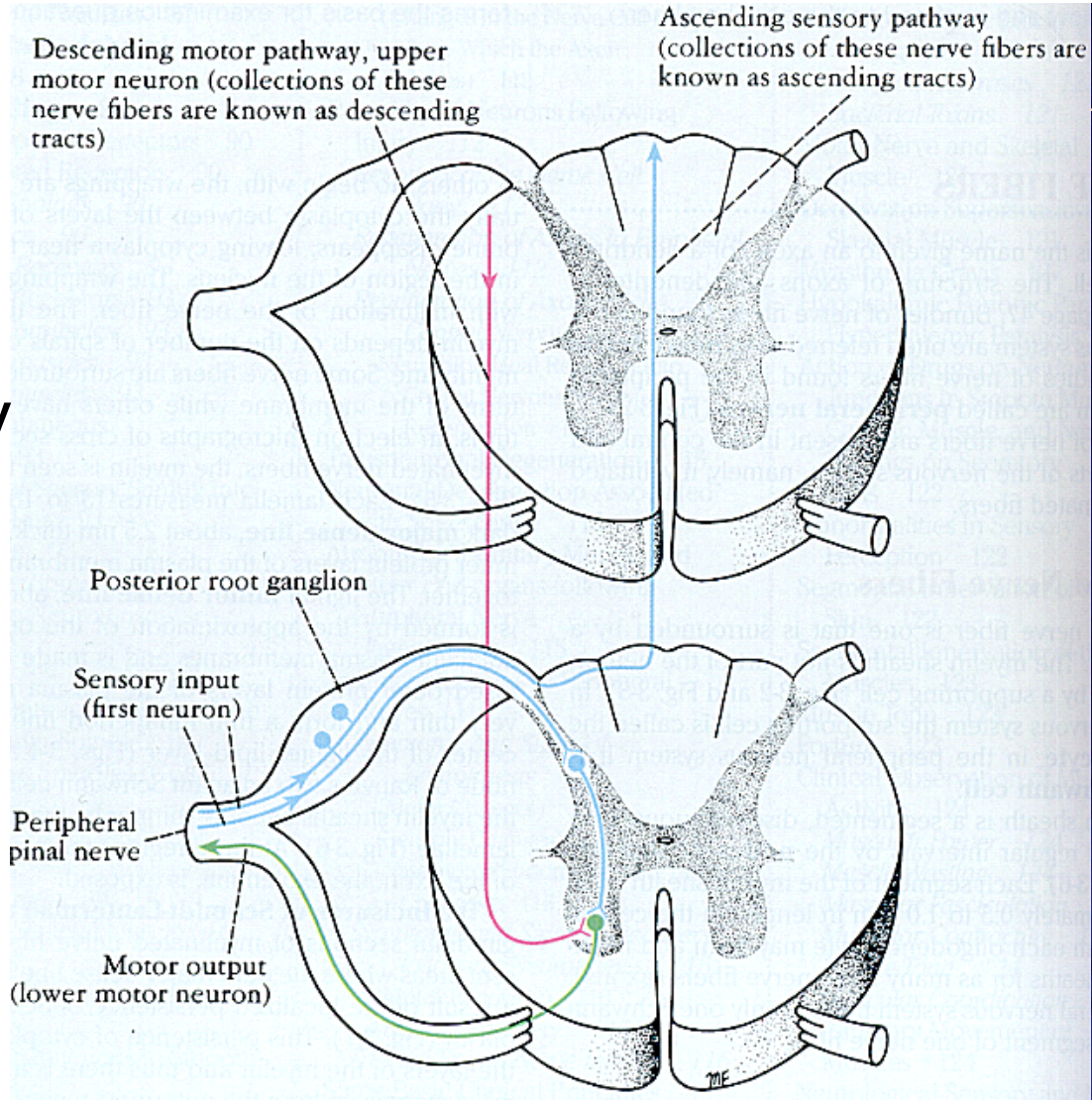
Ascending tracts carry sensory information to the brain.



Descending tracts carry commands to motor neurons.

White Matter

- Divided into columns (funiculi) containing tracts
- Ascending tracts relay info from spinal cord to brain (sensory)
- Descending tracts relay info from brain to cord (motor)


Descending motor pathway, upper motor neuron (collections of these nerve fibers are known as descending tracts)
Ascending sensory pathway (collections of these nerve fibers are known as ascending tracts)
Posterior root ganglion
Sensory input (first neuron)
Peripheral pinal nerve
Motor output (lower motor neuron)

Sensory Physiology

- Sensations & Perceptions
  - sensation - is an awareness of sensory stimuli in brain
  - perception - meaningful interpretation or conscious understanding of sensory data

5 COMPONENTS of SENSORY PHYSIOLOGY

- **Sensory modalities** (receptors)- structures that detect changes in external & internal environment modified neurons or epithelial cells that have evolved to respond to stimuli (eye, ear, nose)

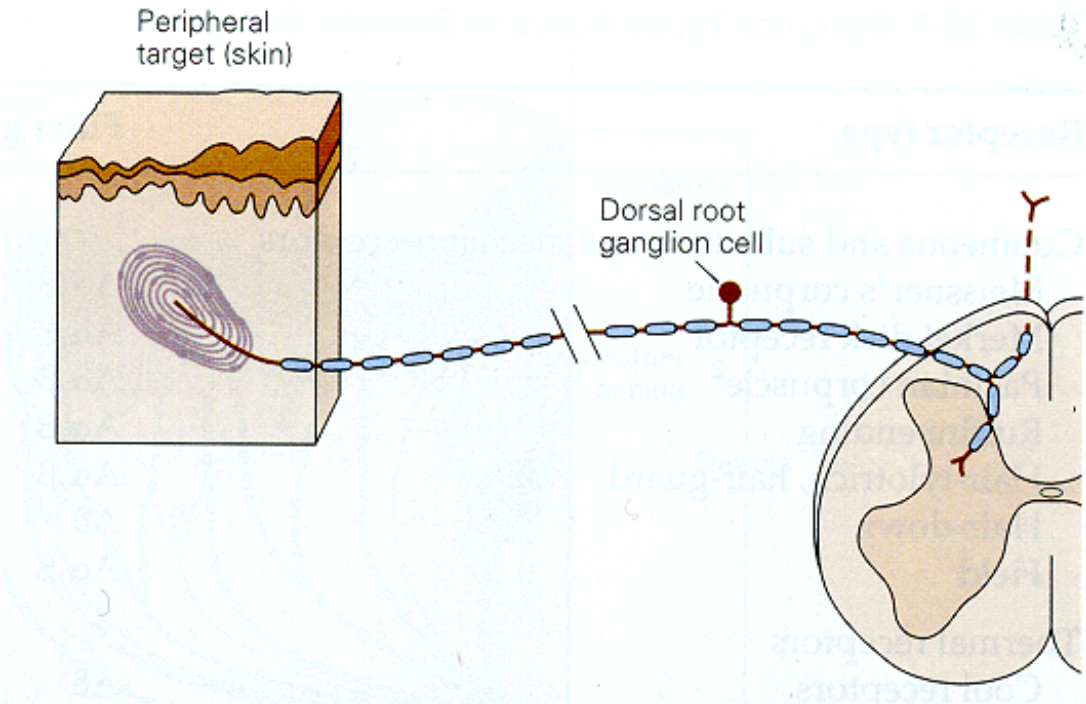
Somatic sensibility has four major modalities

- ***discriminative touch*** -required to recognize the size, shape, and texture of objects and their movement across the skin.
- ***proprioception*** **-**the sense of static position and movement of the limbs and body.
- ***nociception*** -the signaling of tissue damage or chemical irritation, typically perceived as pain or itch.
- ***temperature sense*** -warmth and cold

Classes of Sensory Receptors

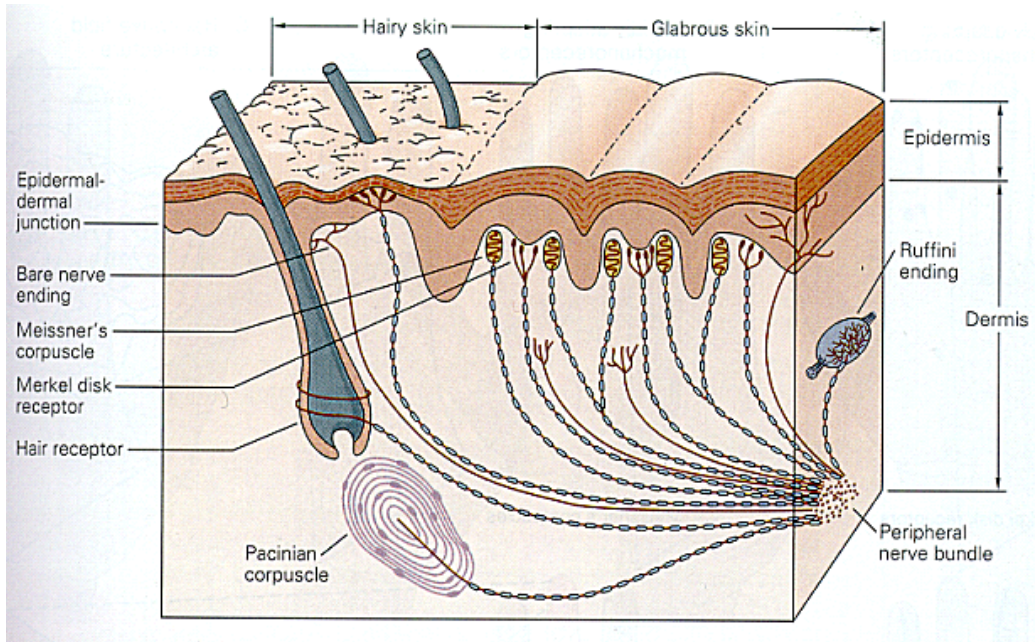
- **mechano-receptors**: mechanical forces - stretching alters membrane permeability
  (1) hair cells (deflection = depolarization = AP's)
  (2) stretch receptors of muscles
  (3) equilibrium receptor of inner ear
  (4) receptors of skin (touch, pain, cold, heat)
- **chemo-receptors**: chemicals sense solutes in solvents, taste, smell
- **osmo-receptors**: of hypothalmus which monitors blood osmotic pressure
- **photo-receptors**: light - eye
- **thermo-receptors**: radiant (heat) energy
- **phono-receptors**: sound waves
- **electro-receptors**: detect electric currents
- **noci-receptors**: pain receptors... naked dendrites of skin (epidermis)

- Irrespective of modality, all **somatosensory information** from the limbs and trunk is **conveyed by dorsal root ganglion neurons**
- The **terminal** of the peripheral **branch** of the axon is the **only portion** of the dorsal root ganglion cell **that is sensitive to natural stimuli.**



The peripheral terminals of dorsal root ganglion neurons are two types.

- The terminal may be a bare nerve ending or the nerve ending may be encapsulated by a nonneural structure.
- Dorsal root ganglion neurons with **encapsulated terminals mediate** the somatic modalities of **touch and proprioception.**
- In contrast, dorsal root ganglion neurons with **bare nerve endings mediate painful or thermal sensations.**



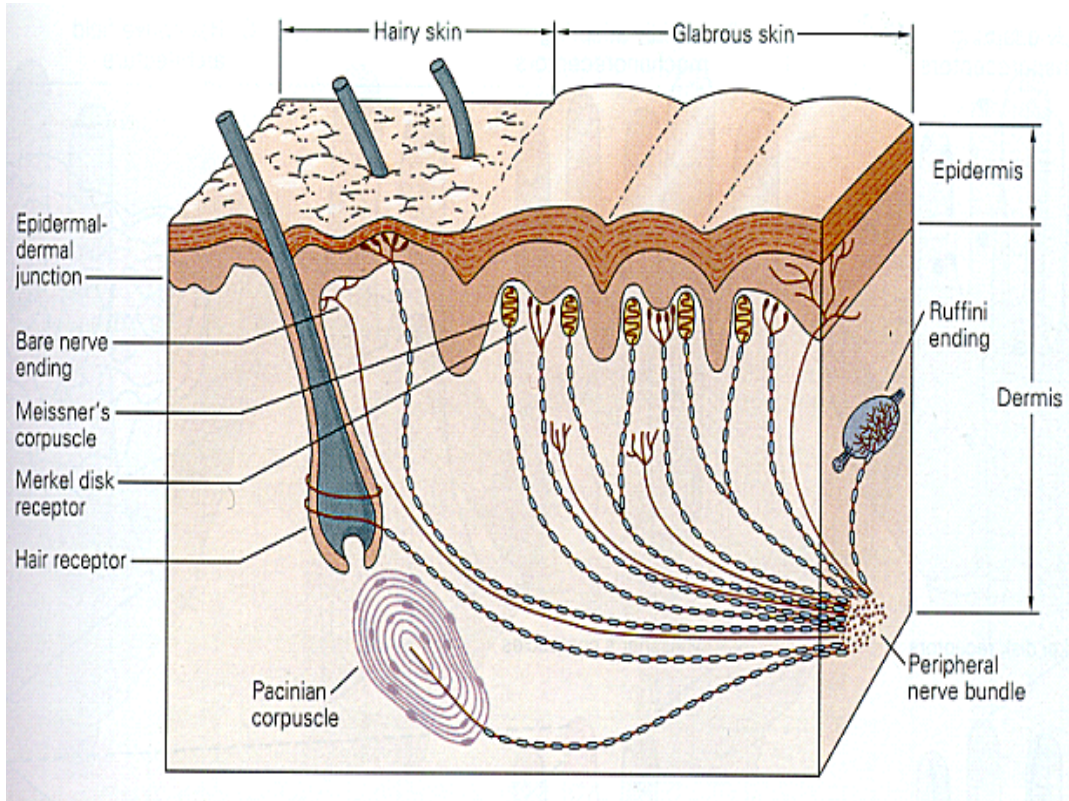
Phasic vs. Tonic Receptors

- Phasic receptors- receptors that **adapt quickly to stimuli** meaning that they initially fire in the presence of a stimulus and then stop are particularly **effective at conveying information about changes** in a stimulus (dynamic info).
- Tonic receptors- receptors that **slowly adapt convey information about the persistence of a stimulus** (static info.)

Skin Receptors

The two principal mechanoreceptors in the **superficial layers** of the skin are the

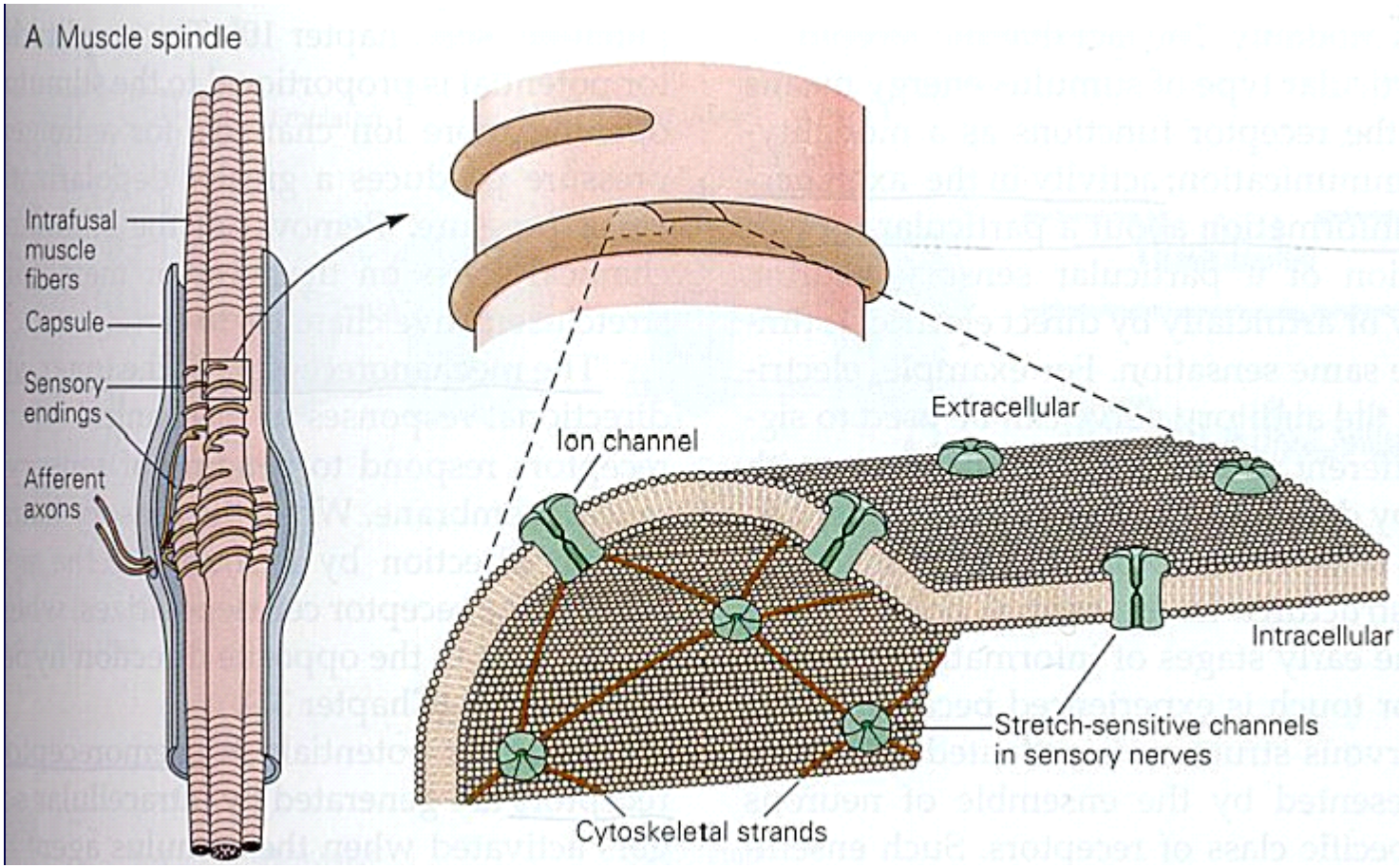
- **Meissner's corpuscle-**
  - **rapidly adapting receptor**, coupled mechanically to the edge of the papillary ridge, a relationship that confers **fine mechanical sensitivity.**
- **Merkel disk** receptor
  - encloses a semirigid structure that **transmits compressing strain** from the skin to the sensory nerve ending, evoking sustained, **slowly adapting response**



Skin Receptors

- The two mechanoreceptors found in the deep subcutaneous tissue are the
- **Pacinian corpuscle**
  - The Pacinian corpuscle **responds to rapid indentation of the skin but not to steady pressure** because of the connective tissue lamellae that surround the nerve ending. (touching a tuning fork (oscillating at 200-300Hz) to the skin)
- **Ruffini ending (corpuscles)**
  - are **slowly adapting receptors** – respond to heavy touch, pressure, stretching, of skin, joint movement
    - (stretch of the skin or bending of the fingernails) Mechanical information sensed by
    - Ruffini ending contributes to our perception of the shape of grasped objects.

Mechanoreceptors (Proprioceptors)



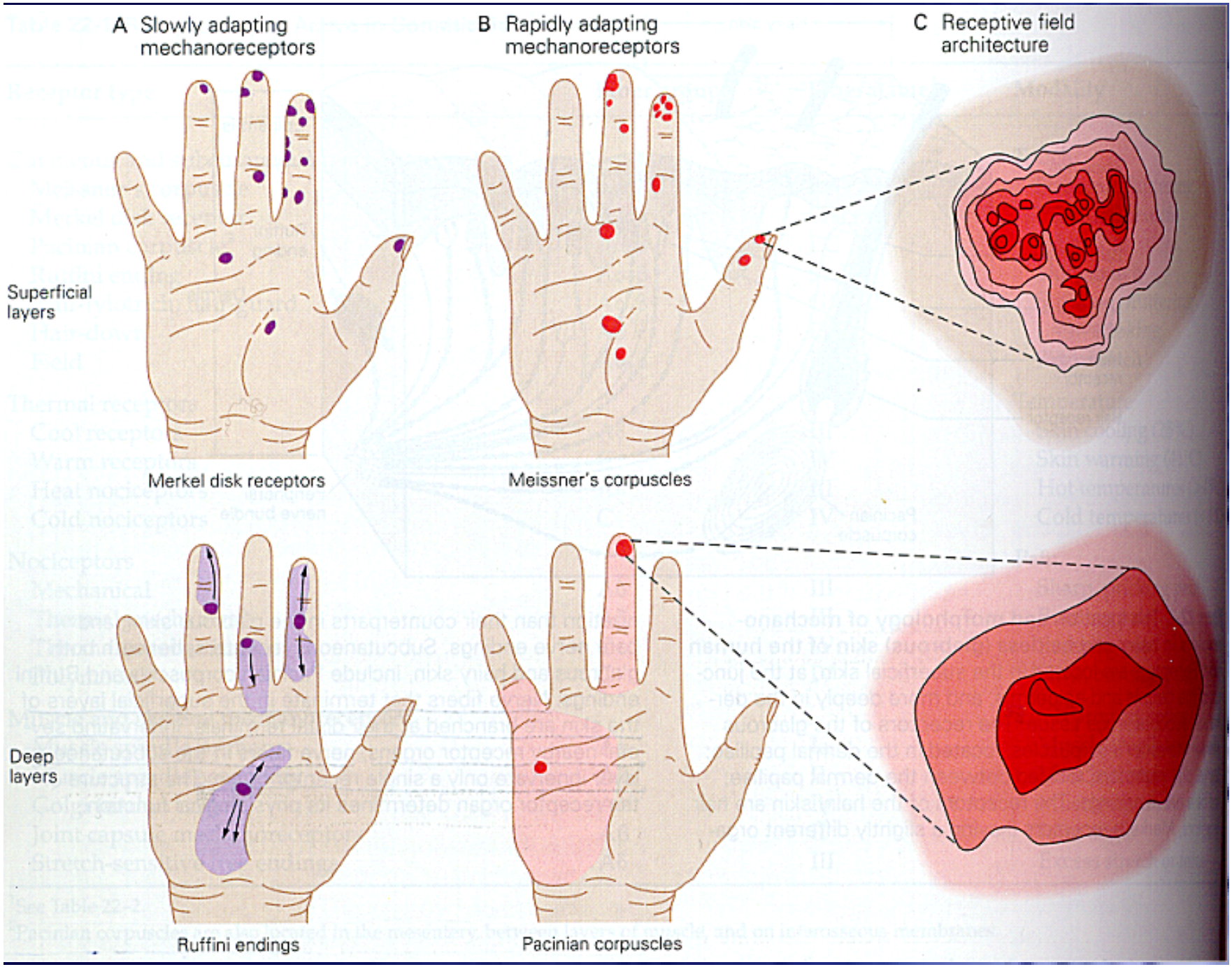
- Receptors **signal muscle length and the speed at which the muscle is stretched**.
- Consists of a bundle of specialized (intrafusal) muscle fibers enclosed by a capsule.
- The sensory nerve endings respond to stretch of the muscle fibers, producing the receptor potential.

Receptor Field

- The region within which a tactile stimulus evokes a sensory response in the cell or its axon.
- Receptor fields vary:
  - receptive fields of mechanosensory neurons are 1-2mm in the fingertips, vs. 5-10 mm on the palms. This indicates that there are more encapsulated mechanoreceptors in the fingertips than in the palm.
  - Receptor fields can be measured by two-point-discrimination, (measure the minimal distance required between two points to perceive two stimuli as distinct.)

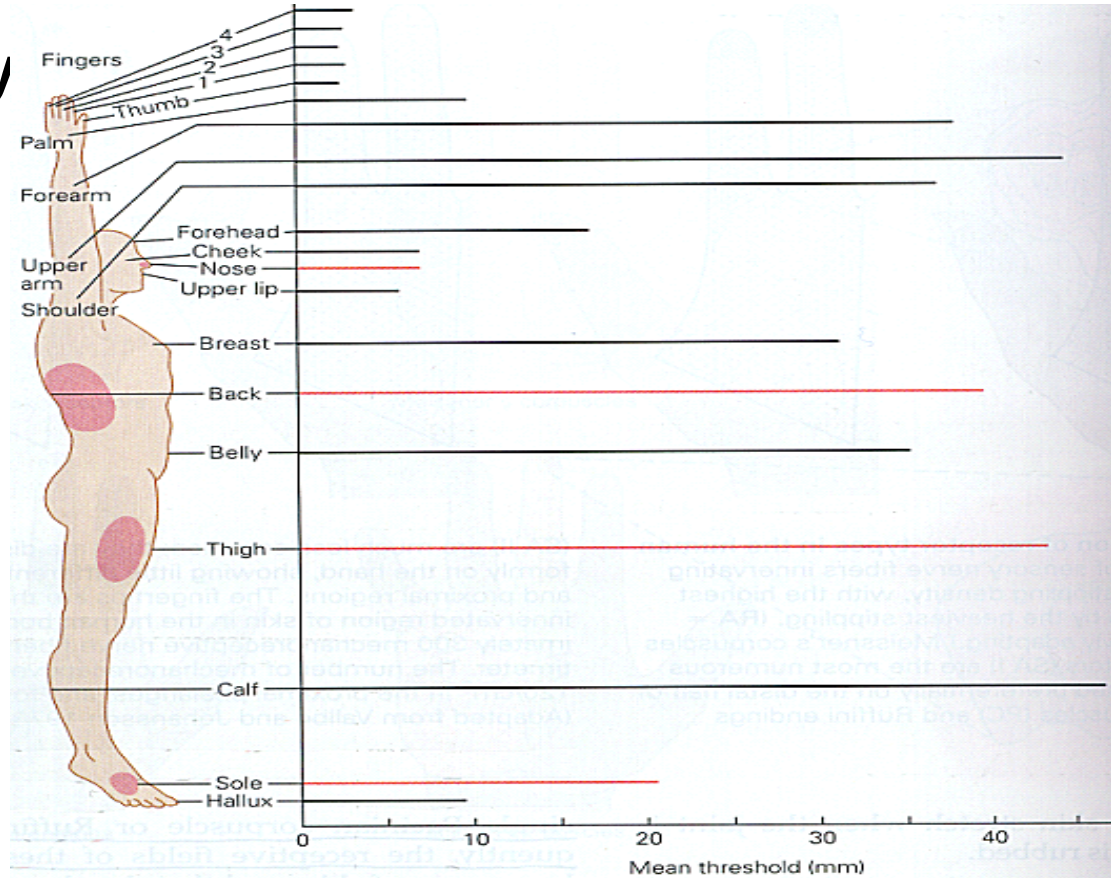
Adpatation

- When the frequency of receptor firing declines after prolonged stimulus exposure
- Tonic receptors adapt slowly and generate nerve impulses more steadily
  - prorpioceptors are among the most slowly adapting tonic receptor because the brain must always be aware of body position, muscle tension and joint motions
- Phasic receptors generate a bust of action potentials when first stimulated, then quickly adapt and sharply reduce or halt signal transmission even if stimulus continues
  - lamellated corpuscles, tactile receptors, hair receptors, and smell receptors are rapidly adapting

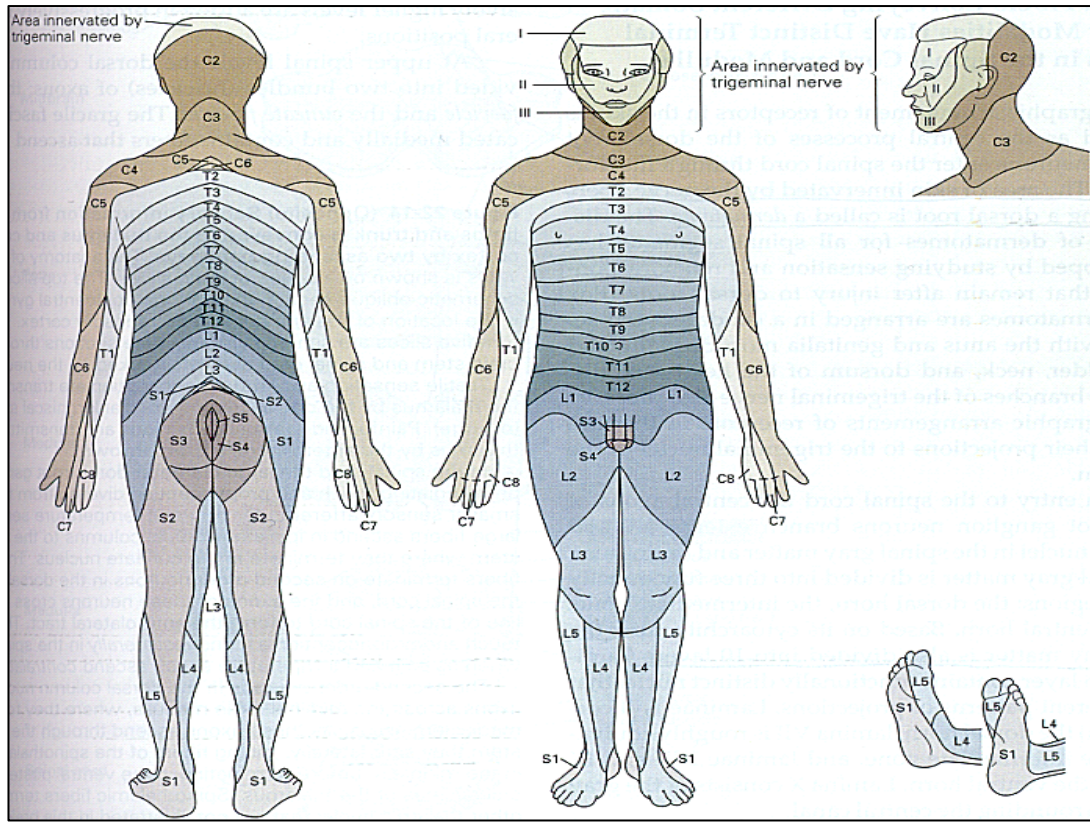

A Slowly adapting mechanoreceptors
B Rapidly adapting mechanoreceptors
C Receptive field architecture
Superficial layers
Merkel disk receptors
Meissner's corpuscles
Deep layers
Ruffini endings
Pacinian corpuscles

Two-Point Discrimination

- The two-point threshold **varies for different body regions**;
- it is about **2㎜ on the finger tip** but increases to **10㎜ on the palm** and **40㎜ on the arm**.
- These variations are **correlated with the size of sensory receptive fields and the innervation density** of mechanoreceptors in the superficial layers of the skin.



- The area of skin innervated by a single dorsal root, known as a **dermatome**,
- Dermatomal maps are an important diagnostic tool for locating the site of injury to the spinal cord and dorsal roots.



Adaptation Curves For Sensory Receptors

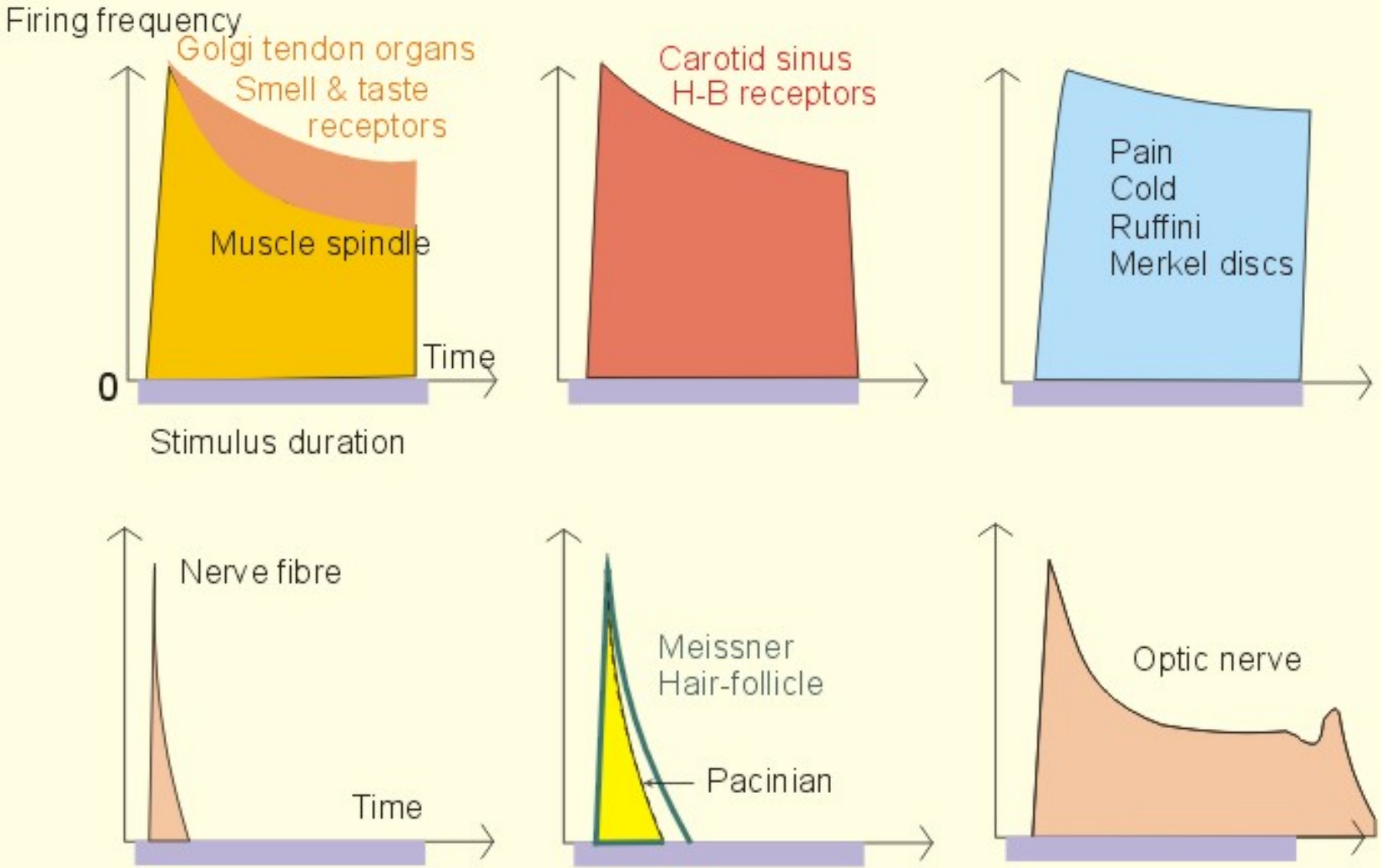


Fig. 3-4

KMc

Proprioceptors

(meaning "reception for self")

- Provide information about mechanical forces arising from with the body (particularly the musculoskeletal system).
- Their purpose is to provide detailed and consistent information about the position of the limbs in space.

There are three low-threshold proprioceptors:

1) **Muscle spindles**:
   - located in skeletal muscle, they are especially numerous in extraocular muscles and intrinsic muscles of the hand and neck.
   - signal changes in muscle length

2) **Golgi tendon organs**:
   - distributed among collagen fibers that form tendons
     job
   - inform CNS about changes in mm tension

3) **Joint receptors**
   - located in and around joints
   - gathers info about limb position and joint movement (function is not well understood)

Somatosensory System

These sensory modalities are lumped into three different pathways in the spinal cord and have different targets in the brain.

- **Discriminative touch-** includes touch, pressure, and vibration perception, and enables us to "read" raised letters with our fingertips, or describe the shape and texture of an object without seeing it.
- **Pain and temperature**,
- **Proprioception-** includes receptors for what happens below the body surface: muscle stretch, joint position, tendon tension, etc.
  - This modality primarily targets the **cerebellum**, which needs minute-by-minute feedback on what the muscles are doing.

Somatosensory System

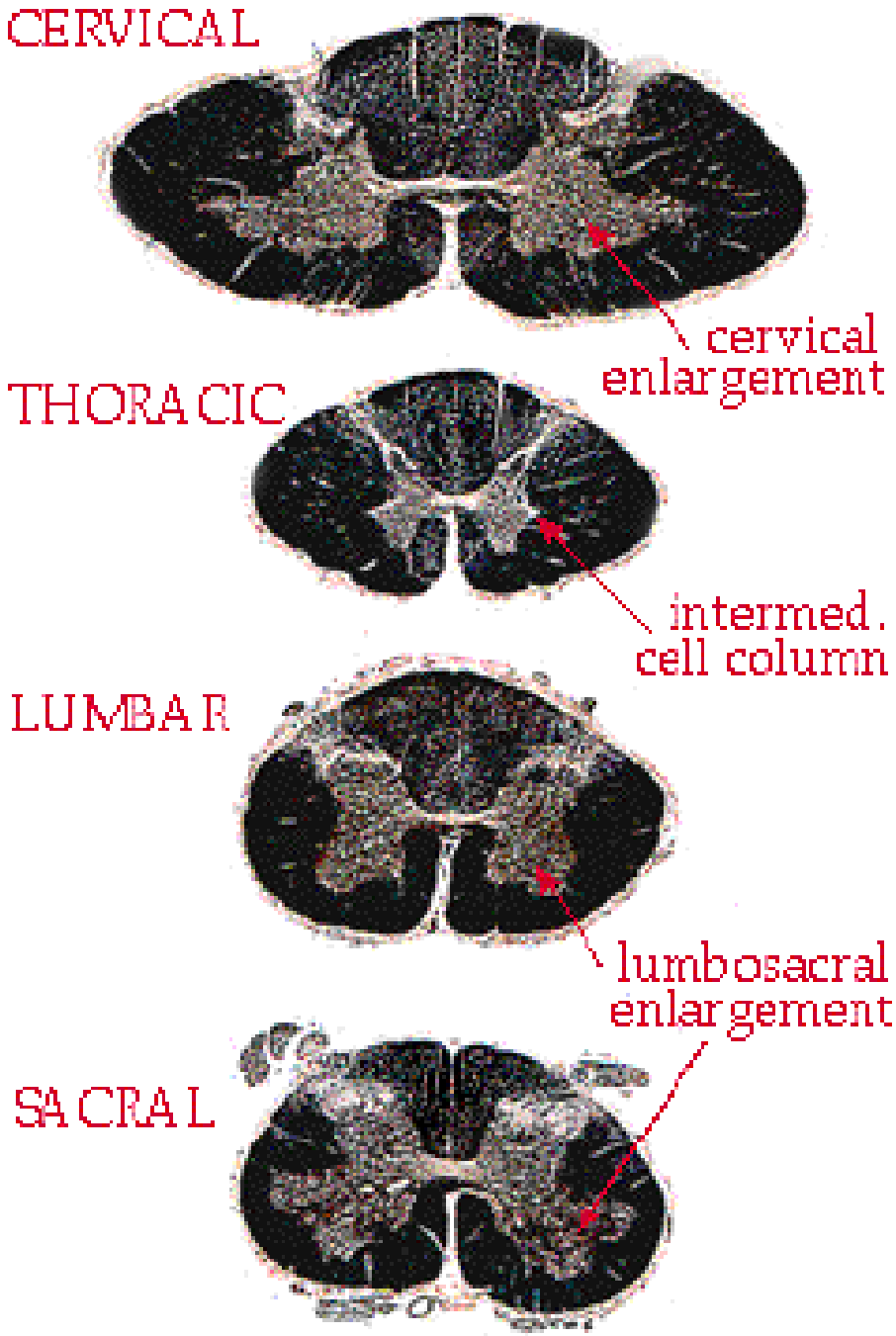
- These modalities differ in their receptors, pathways, and targets, and also in the level of crossing.
- Any sensory system going to the cerebral cortex will have to cross over at some point, because the cerebral cortex operates on a contralateral (opposite side) basis.
- The discriminative touch system crosses high - in the medulla.
- The pain system crosses low - in the spinal cord.
- The proprioceptive system is going to the cerebellum, which (surprise!) works ipsilaterally (same side). Therefore this system doesn't cross.

5 COMPONENTS of SENSORY PHYSIOLOGY

2. Reception - ability of receptor to absorb energy of a stimulus
3. Transduction - conversion of stimulus energy into membrane potential
4. Transmission - receptor potentials transmitted via AP's to CNS
5. Integration - processing of frequency of receptor potentials

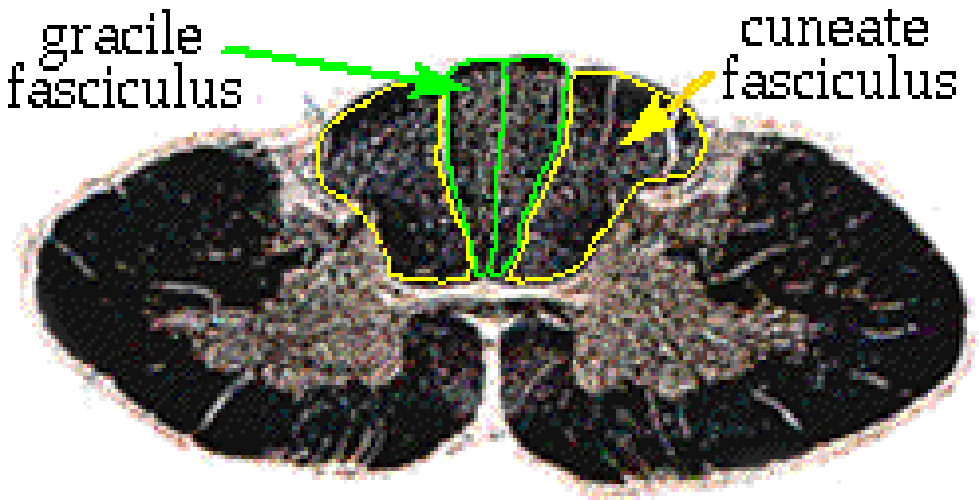
Differentiating Levels of the Cord

- wide flat cord, lots of white matter, ventral horn enlargements = cervical.
- Round cord, ventral horn enlargements = lumbar.
- Small round cord, almost no white matter = sacral.
- the intermediate horn, or the **intermediolateral cell column**.
  - It is the source of all of the sympathetics in the body, and occurs **only in thoracic sections.**



Sensory (Ascending) Tracts

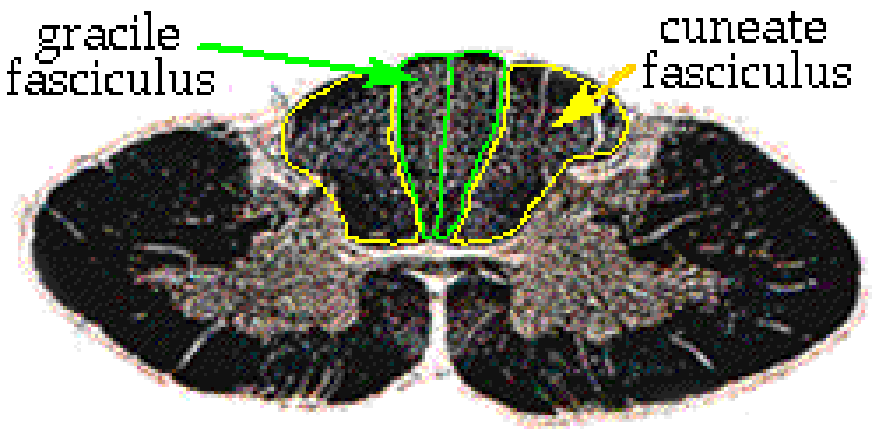
- Since the tracts are on the dorsal side of the cord, they are sometimes called the **dorsal columns** or **posterior columns.**
- the posterior columns can actually be divided into two separate tracts.
  - The midline tracts are tall and thin, and are given the name **gracile fasciculus** (gracile means slender, and fasciculus means a collection of axons).
  - The outer tracts are more wedge shaped, and were given the name **cuneate fasciculus** (cuneate means wedge-shaped).



Sensory (Ascending) Tracts

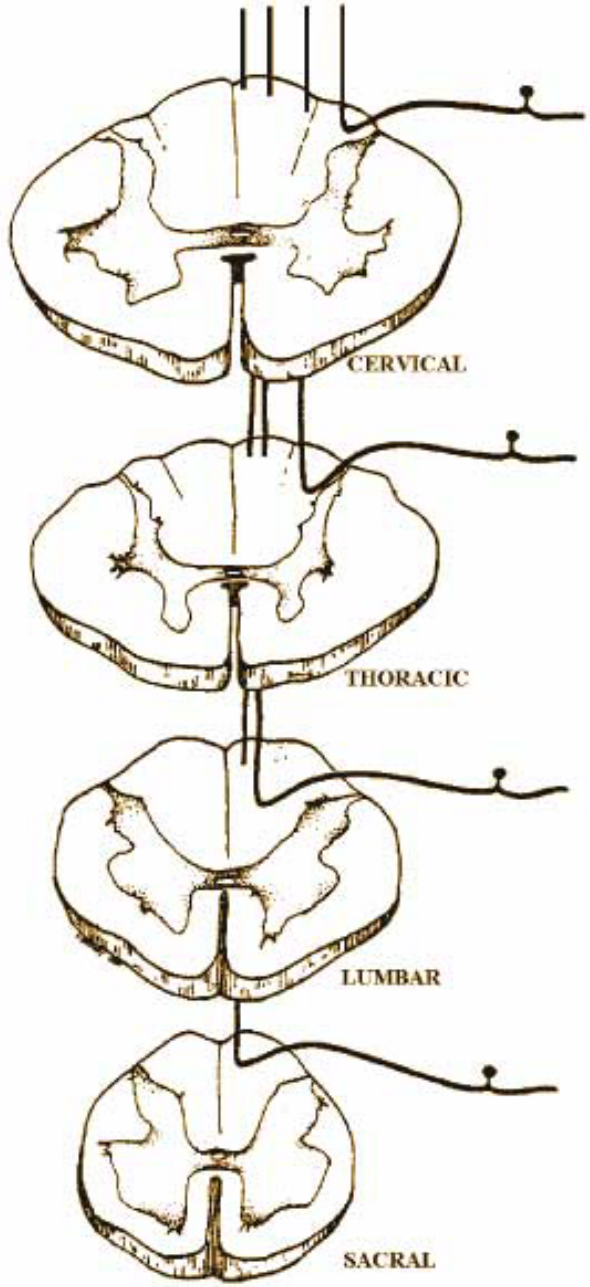
- Fibers carry signals for vibration, visceral pain, deep and discriminative touch (touch whose location one can precisely identify) and especially proprioception (nonvisual sense of the position and movement of the body)

- The gracile fasciculus is carrying all of the **information from the lower half of the body** (T6, midthoracic and below)
- The cuneate fasciculus is carrying **information from the upper half of the body** (T6 from the upper limb and chest).



Somatotopic Oganization

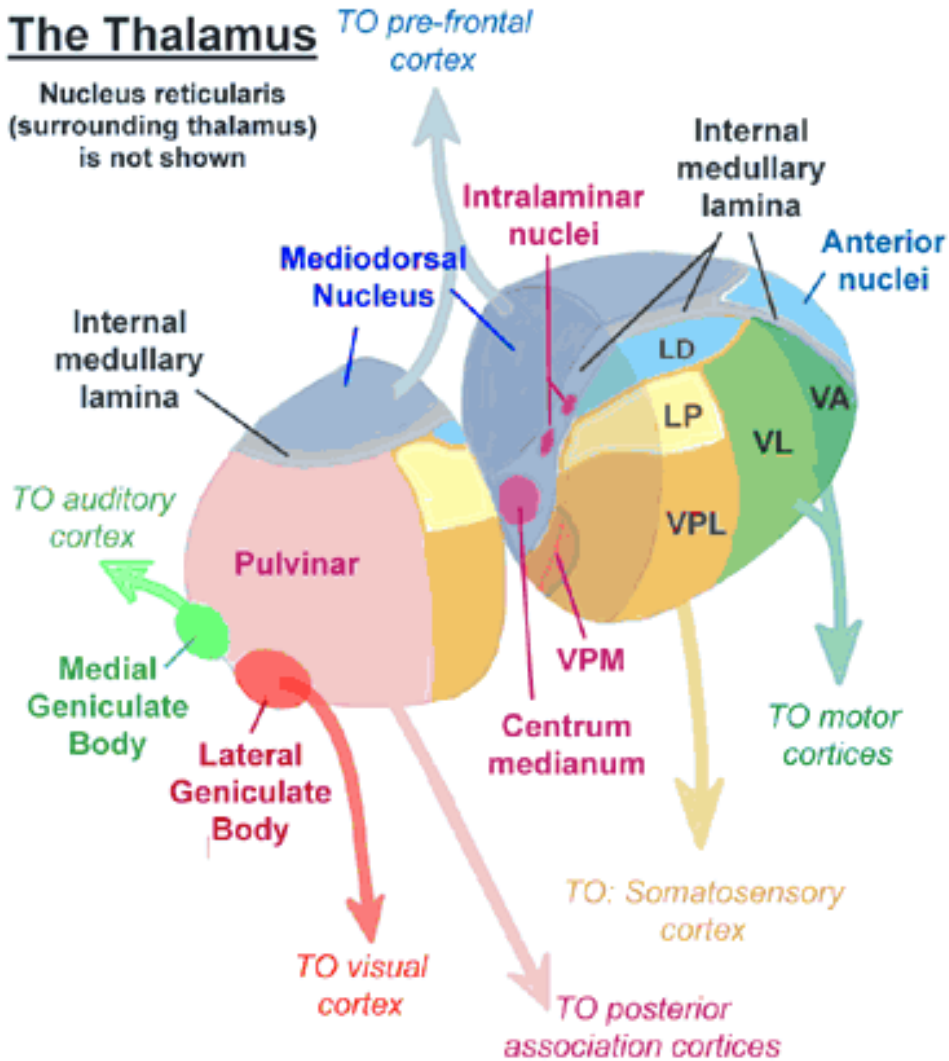
- There is a somatotopic representation of the body in the dorsal columns (fasciculus gracilis and fasciculus cuneatus).
- **Caudal** (sacral and lumbar) body **parts** are represented **medially**
- **Rostral** segments (upper thoracic and cervical) are represented **laterally**.
- Nucleus **gracilis** receives its input from about **T7 and downward,**
- While nucleus **cuneatus** receives its input from spinal levels **above T7**



SOMATOTOPIC ORGANIZATION
OF THE DORSAL COLUMNS

The Role of the Thalamus in Sensory Processing

- Brain region that serves as a switching center for all sensory signals passing from the brain stem to other brain regions EXCEPT SMELL.
- There are 2 thalami, and they are located on either side of the 3rd ventricle.
- Contains many nuclei but 3 are important for sensory processing
  - the ventral posterior medial (VPM) and lateral nuclei (VPL)
  - the lateral geniculate nucleus
  - the medial geniculate nucelus.



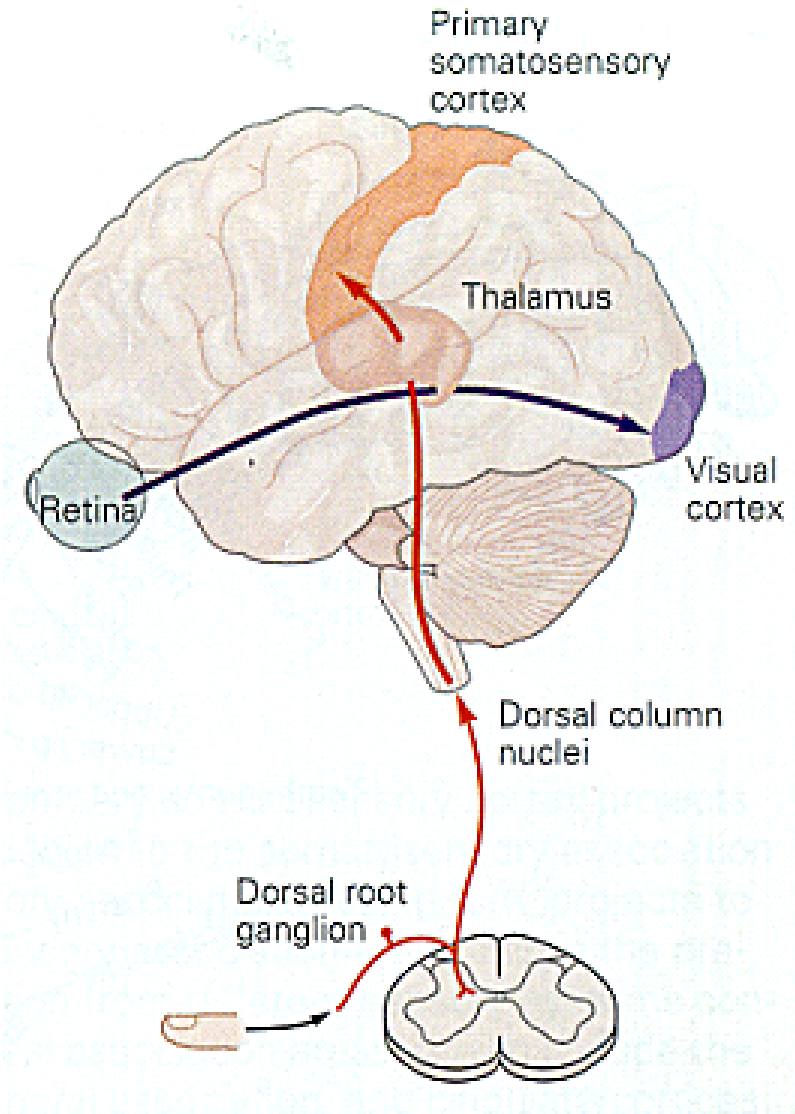
•stimuli applied to the skin causes deformation or change in nerve ending which

•affects ionic permeability and thus a depolarizing current in nerve endings

•produces a receptor potential which triggers action potentials

•the APs travel through the spinal cord, brainstem, and thalamus to reach the primary somatic sensory cortex in the postcental gyrus of the parietal lobe

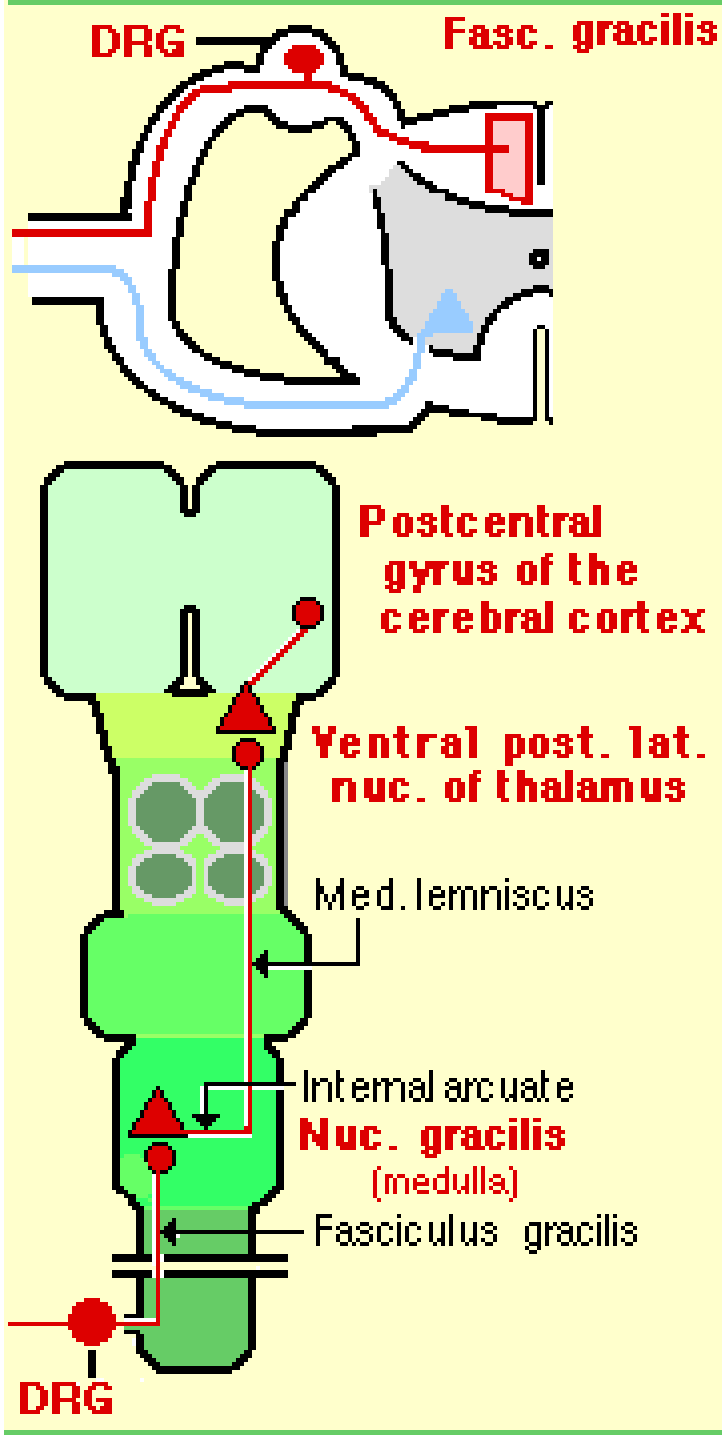
•(from there info is sent to the secondary somatosensory cortex (SII) and from there projections are sent into limbic structures such as the amygdala and hippocampus).



Spinal Sensory Pathways

Fasciculus gracilis

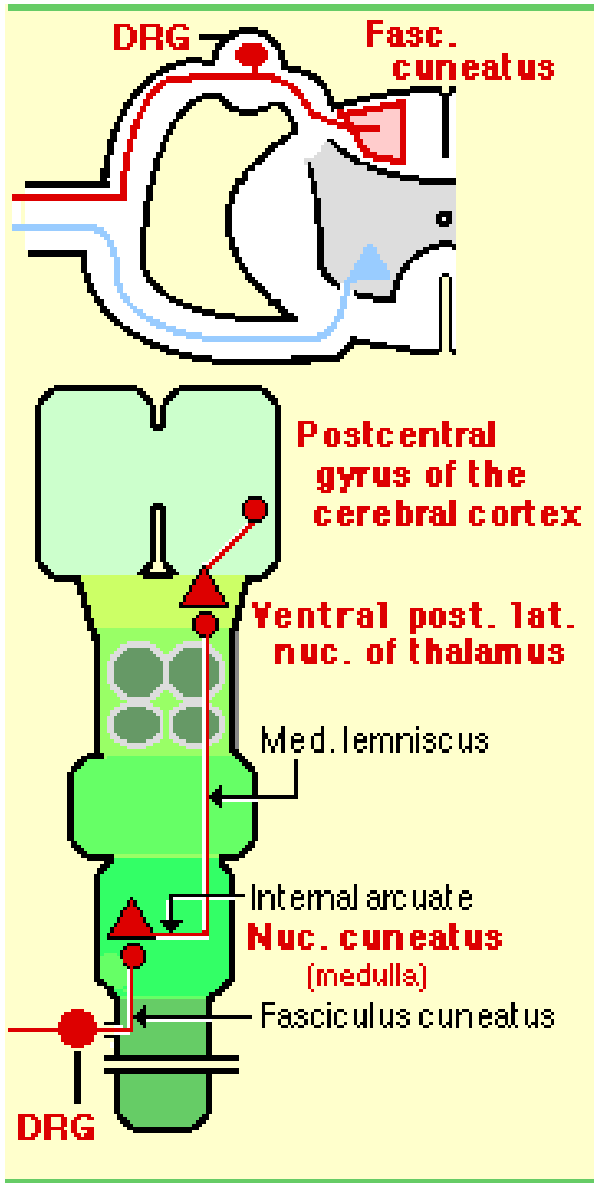
- **The majority of the fibers do not synapse until they reach the medulla.**
- These **fibers arise in dorsal root ganglia of sacral and lumbar segments** of the spinal cord.
- Presynaptic fibers are routed to the nucleus gracilis.
- The **gracile nucleus lies medial to the cuneate nucleus on each side**.
- The postsynaptic paths of cuneatus and gracilis are parallel from this point.
- When 3° gracilis axons reach cerebral cortical level, they are directed to the dorsal side of the cerebral hemisphere, whereas the cuneate data is sent to the lateral and ventral part of the gyrus.



Spinal Sensory Pathways

fasciculus cuneatus

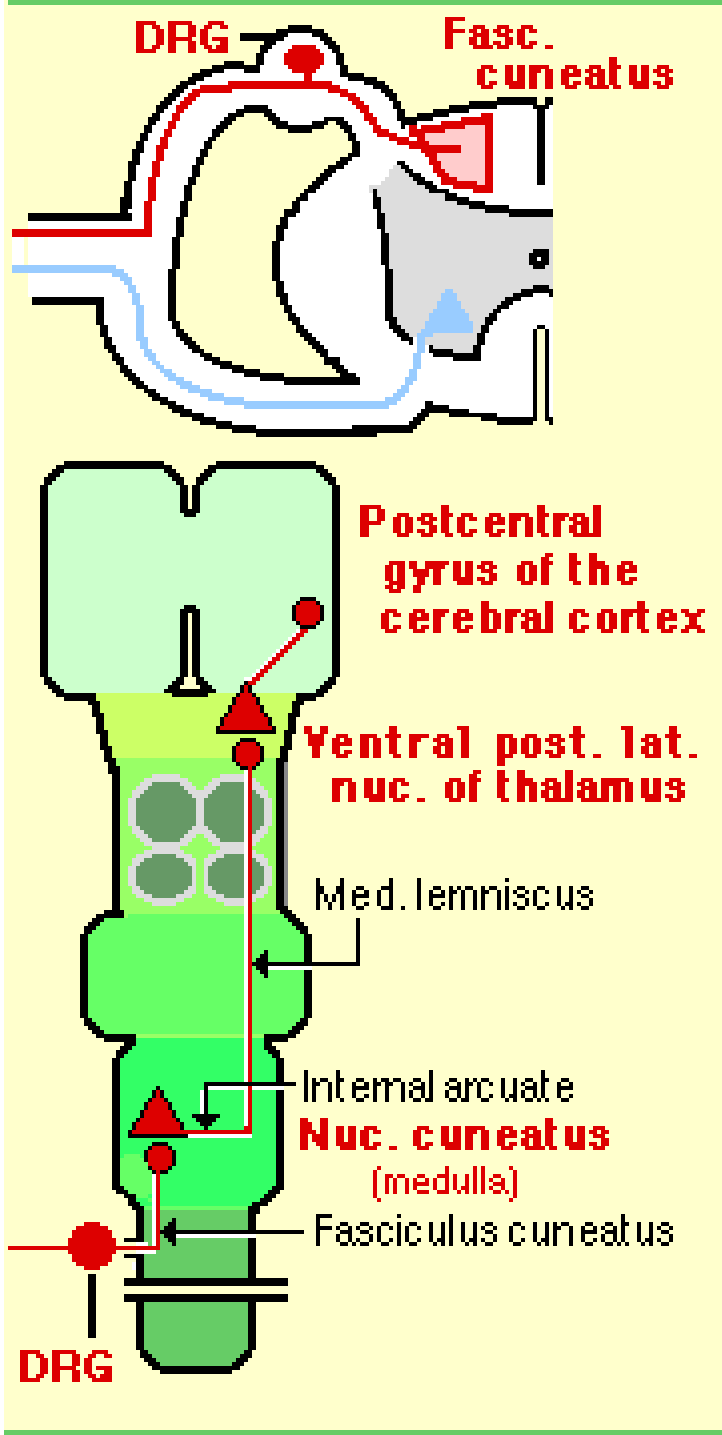
- Cuneate fibers **arise from thoracic and cervical nerves.**
- The majority of the **fibers do not synapse until they reach the medulla.**

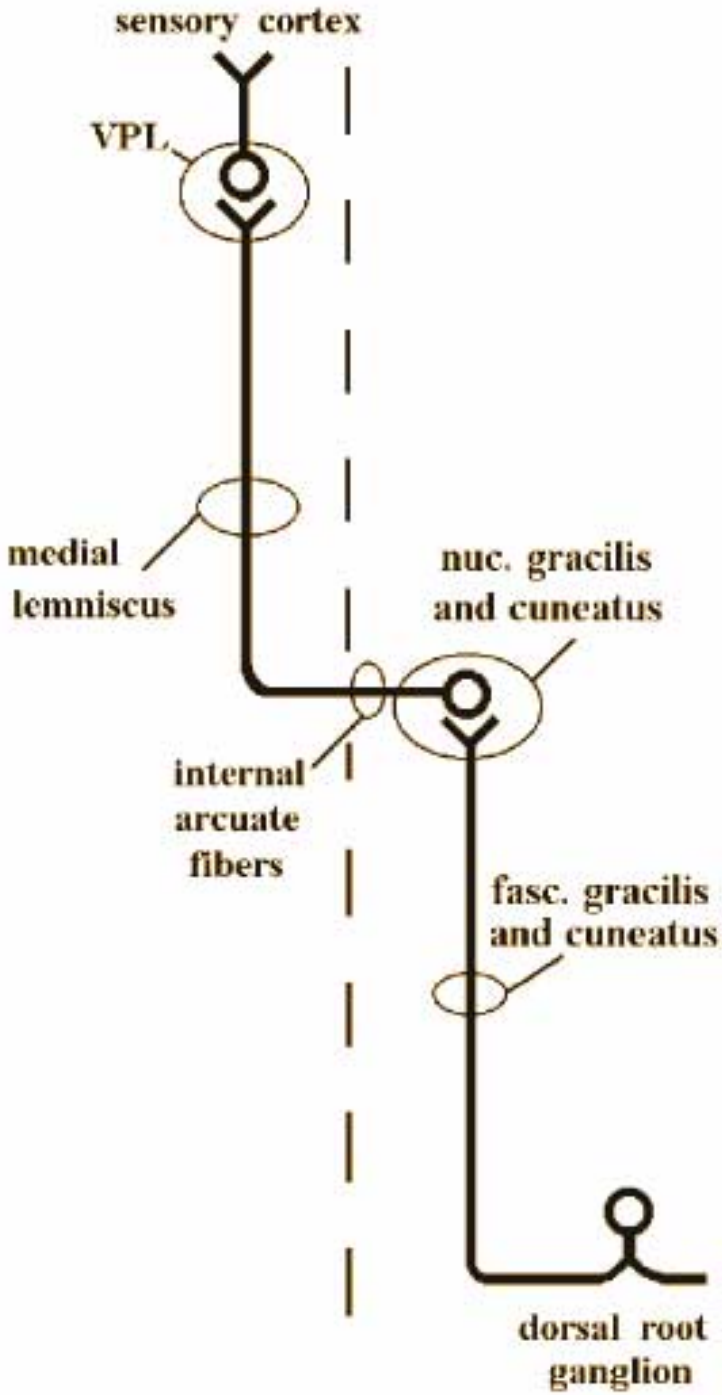


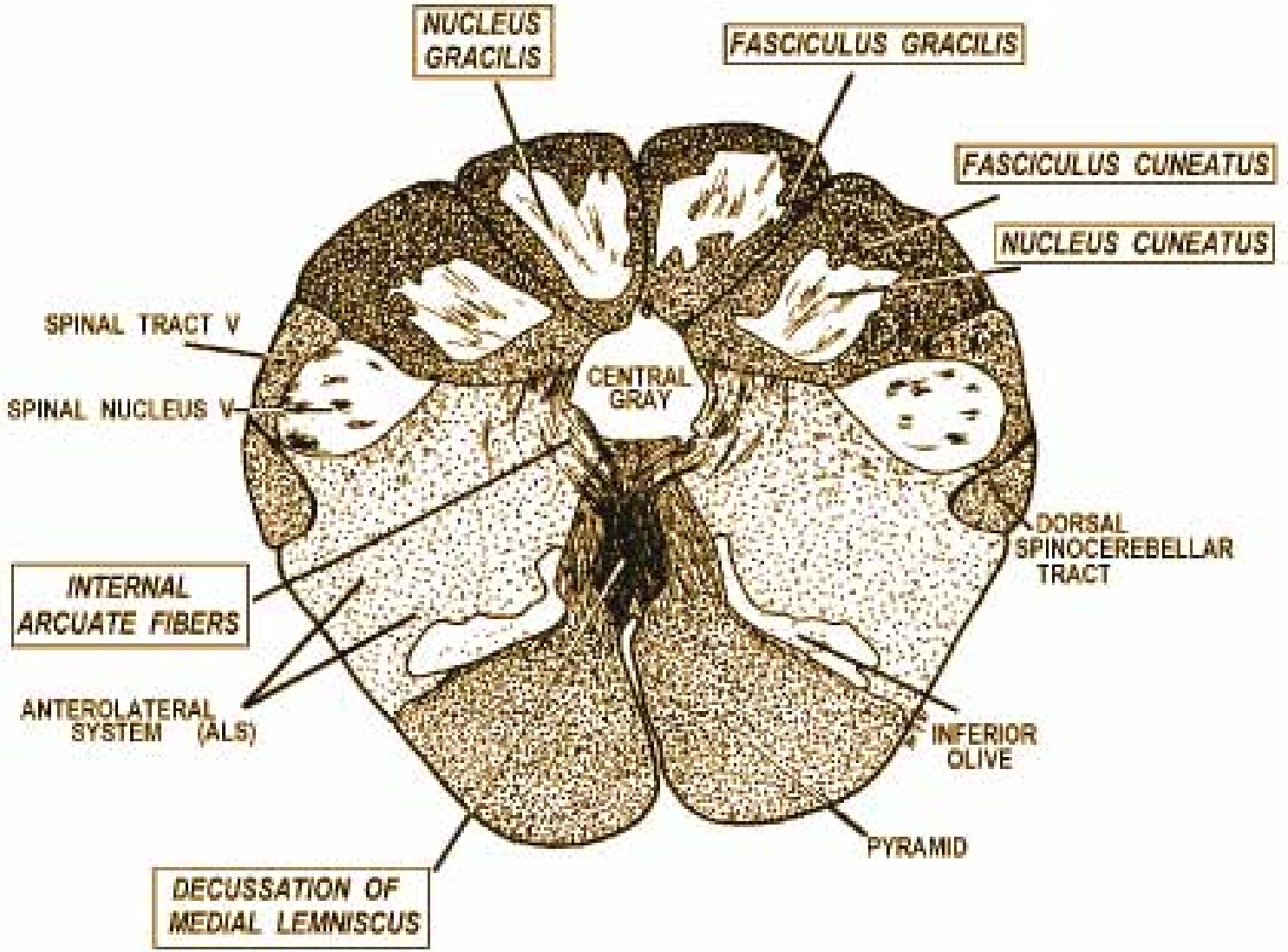
Spinal Sensory Pathways

- Cuneate axons **ascend in the dorsal cord on the ipsilateral side** and synapse in the **nucleus cuneatus** in the dorsal lateral medulla.
- **Postsynaptic fibers cross immediately to the contralateral** side via bands of axons known as the '**internal arcuate fibers**' and enter the massive ascending pathway, the **medial lemniscus**.
- **Lemniscal axons ascend** without synapse until they reach the **ventral posterior lateral nucleus (VPL) of the thalamus**.

  (All sensory input to the brain, with the exception of olfactory, is processed in the thalamus)
- Axons arising in VPL **ascend to the cerebral cortex in the postcentral gyrus** (Brodeman areas 1, 2, 3, and 5), where 'local sign' of **touch sensation is recognized.**

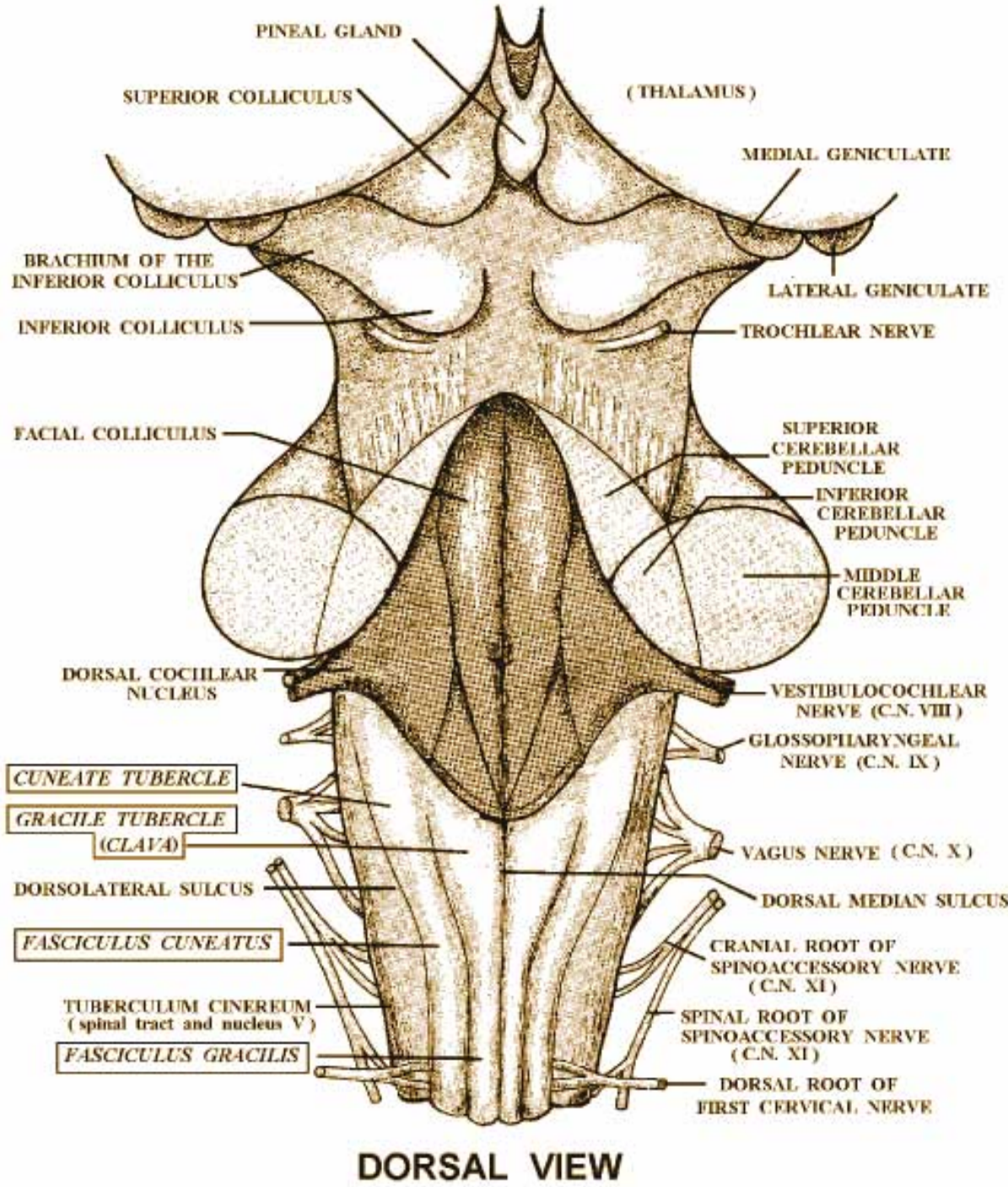



sensory cortex
VPL
medial
lemniscus
nuc. gracilis
and cuneatus
internal
arcuate
fibers
fasc. gracilis
and cuneatus
dorsal root
ganglion



LEVEL 2. DECUSSATION OF MEDIAL LEMNISCUS

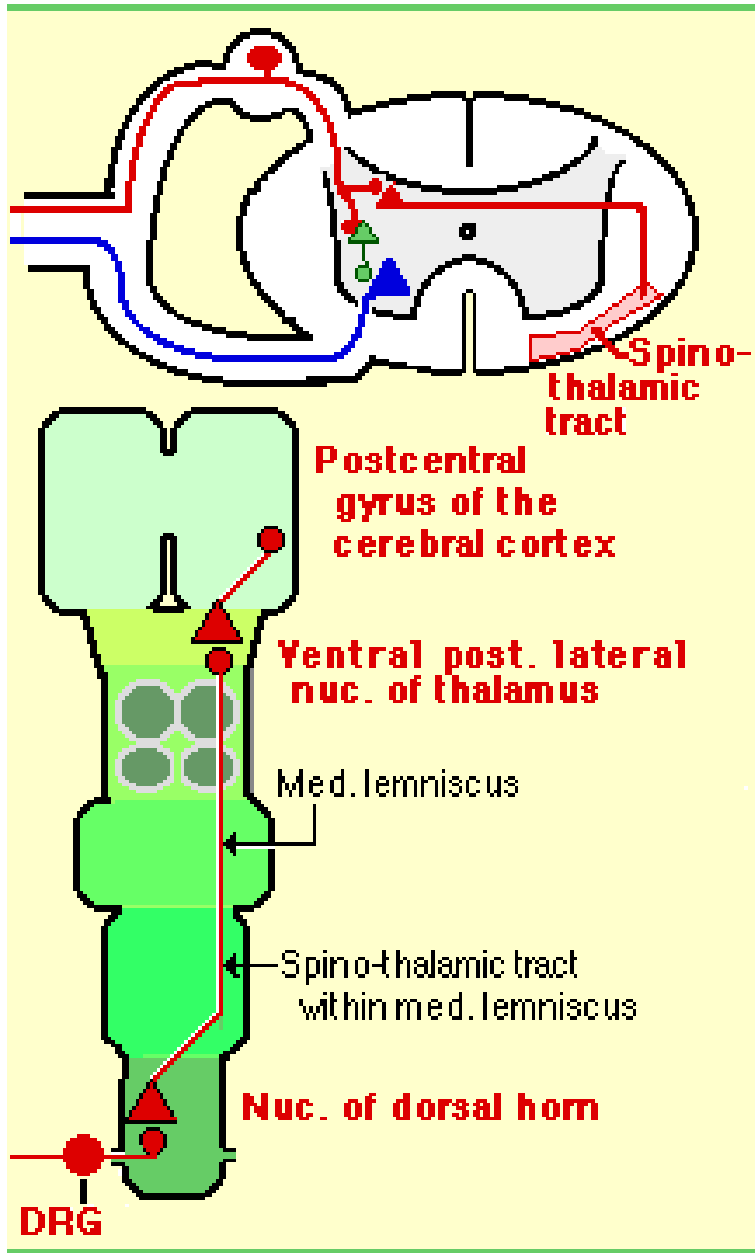
- These two nuclear groups and their associated fasciculi can be seen as slight **swellings on the dorsal surface of the medulla.**
- The bump formed by nucleus and fasciculus gracilis is called the **gracile tubercle**
- and that caused by nucleus and fasciculus cuneatus is called the **cuneate tubercle**.



Spinal Sensory Pathways

Lateral Spinothalamic Tracts

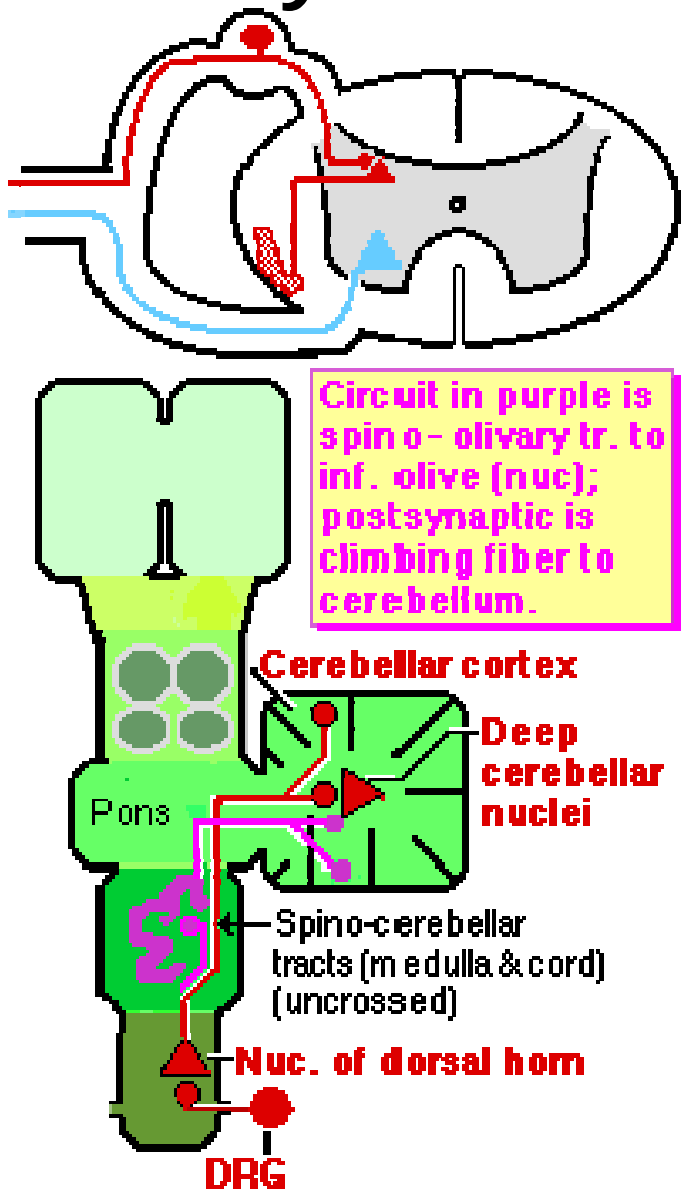
- **principal pathways pain, temperature, pressure, tickle, itch, and light or crude touch.**
  - light touch-sensation produced by stroking hairless skin with a feather or cotton wisp
  - crude touch- location can only vaguely identify
- **Pain fibers** are small and usually unmyelinated, while **thermal fibers** usually have myelin.
- first order neurons synapsis occurs in the dorsal horn
- Postsynaptic (second order) neurons decussate to form the ascending spinothalamic tract.
- They ascend through the lower brain stem in the **medial lemniscus.**



Spinal Sensory Pathways

Dorsal and Ventral Spinocerebellar Pathways

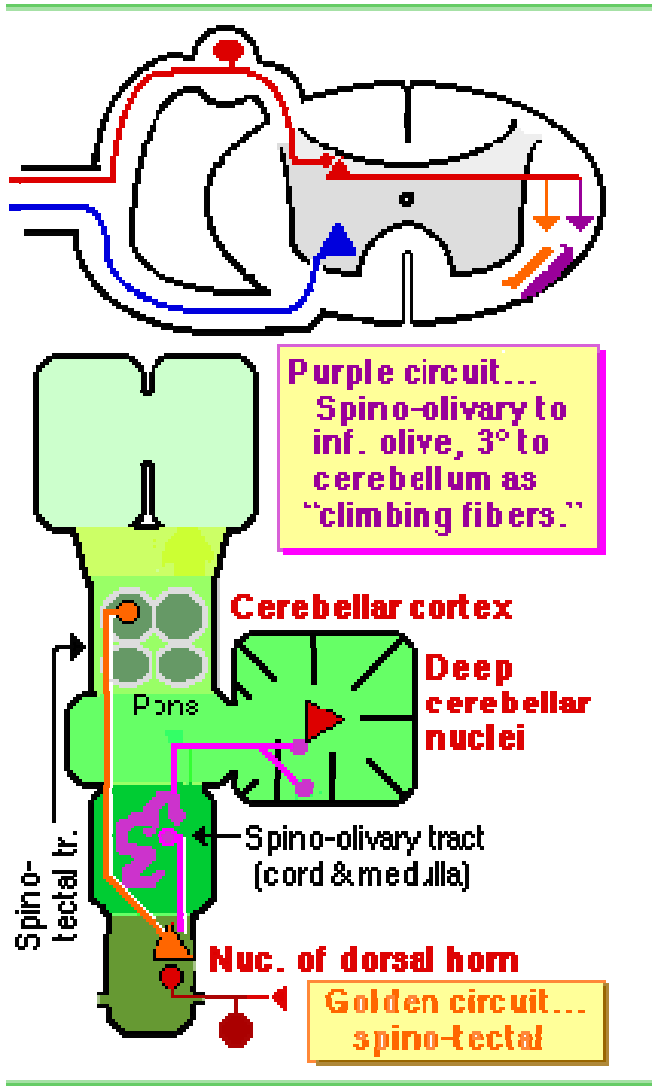
- Spinocerebellar fibers **carry proprioceptive signals from the limbs and trunk to the cerebellum**
- After synapsing in the dorsal gray horn, 2° **axons ascend in the dorsal or ventral spinocerebellar** tracts.
  - dorsal tract travel ipsilateral
  - ventral cross, ascend, cross back in brainstem to enter ipsilateral Cerebellum
- **enter the cerebellum** as mossy fibers, and the next level of synapses is there, in the deep cerebellar nuclei and onto the granule cells of the cerebellar cortex


Circuit in purple is spino-olivary tr. to inf. olive (nuc); postsynaptic is climbing fiber to cerebellum.
Cerebellar cortex
Deep cerebellar nuclei
Pons
Spino-cerebellar tracts (medulla & cord) (uncrossed)
Nuc. of dorsal horn
DRG

Spinal Sensory Pathways

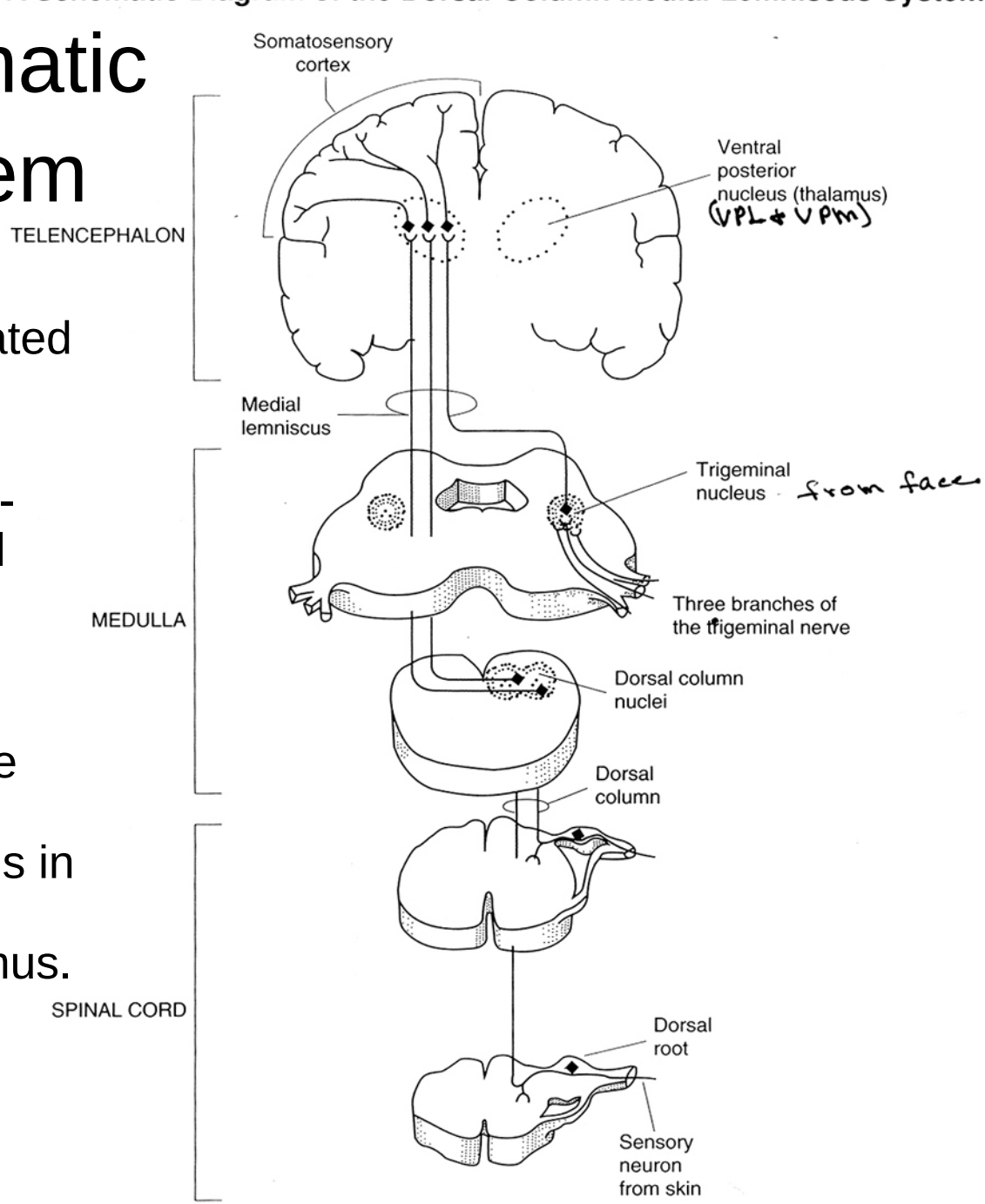
Spinotectal tract—

- in terms of receptors, this is a spinothalamic subdivision, but it **synapses in the sup. colliculus** of the mesencephalon, rather than continuing to the thalamus.
- Functionally, it **transmits typical spinothalamic impulses (touch) into the tectum**, where it **drives reflexes, aiming the head (gaze)** at the location of sensory input on the body surface (a bee stings, you rapidly look at the bee!).



Trigeminal somatic sensory system

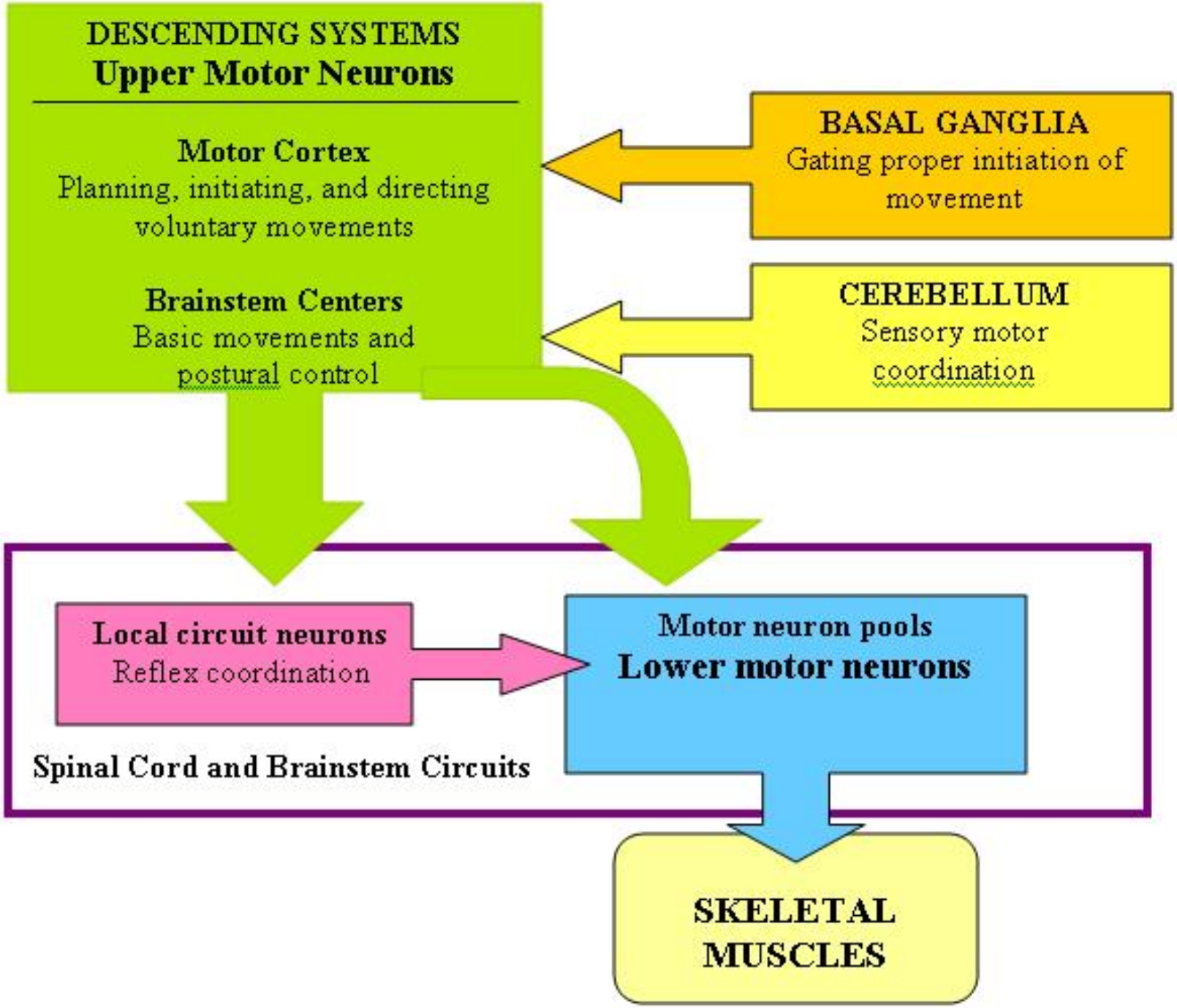
- Low-threshold mechano-reception in the face is mediated by first-order neurons in the trigeminal (CN V) ganglion.
- These connect to the second-order neurons in the principal nucleus of the trigeminal complex (mid-pons) which
- then travel as the trigeminothalamic tract (or the trigeminal lemniscus) and connect to third-order neurons in the VPM (ventral posterior medial) nucleus of the thalamus.



Movement and Its Central Control

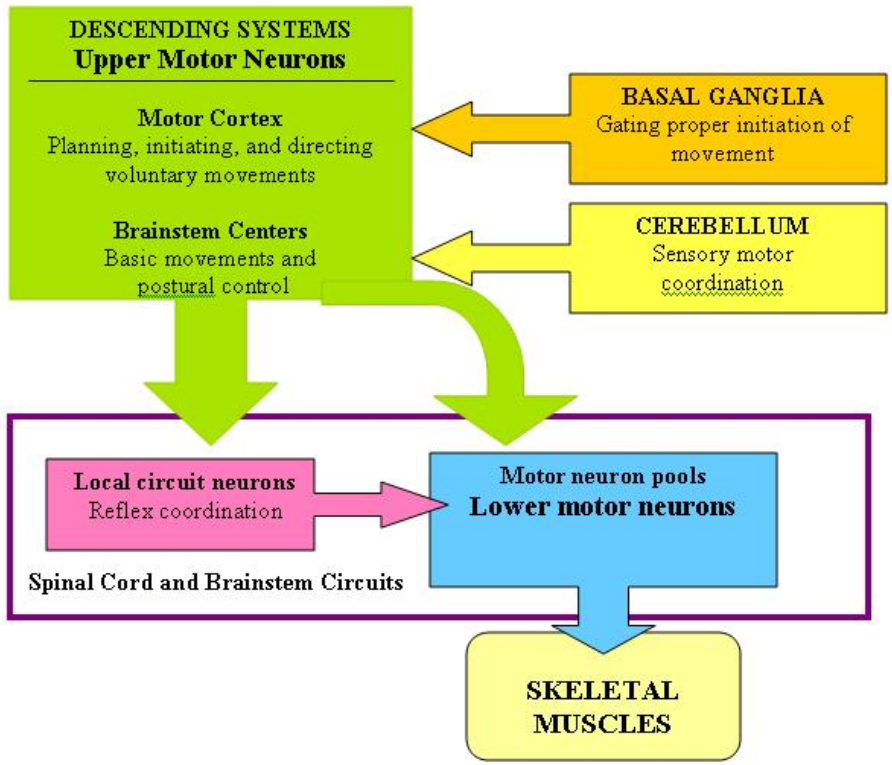
Neural circuits responsible for the control of movement can be divided into four distinct but highly interactive subsystems:

- Descending Modulatory Systems
- Local Spinal Cord and Brainstem Circuits
- Basal Ganglia
- Cerebellum


DESCENDING SYSTEMS
Upper Motor Neurons
Motor Cortex
Planning, initiating, and directing voluntary movements
Brainstem Centers
Basic movements and postural control
BASAL GANGLIA
Gating proper initiation of movement
CEREBELLUM
Sensory motor coordination
Local circuit neurons
Reflex coordination
Motor neuron pools
Lower motor neurons
Spinal Cord and Brainstem Circuits
SKELETAL MUSCLES

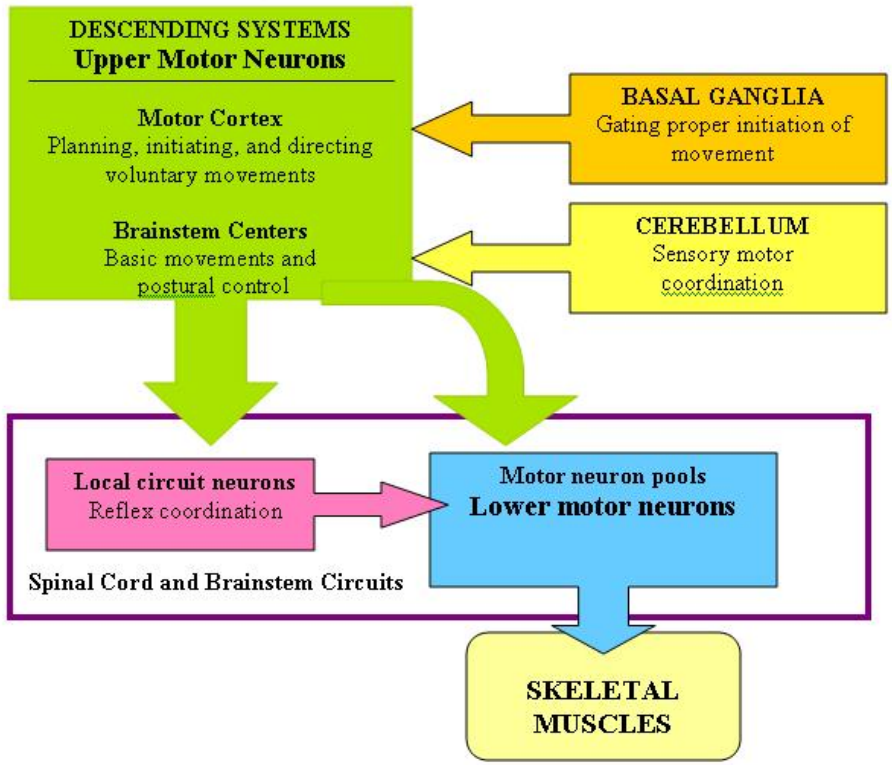
Descending Modulatory Pathways (Upper Motor Neurons)

- The **cell bodies** for these pathways **lie in the brainstem or cerebral cortex** and descend to synapse with the local circuit neurons or, more rarely, with lower motor neurons directly.
- **Motor cortex pathways** descending from areas such as the primary motor cortex, the lateral premotor cortex, and the medial premotor cortex, **are required for the planning, initiation and direction of temporal sequences of voluntary movement.**
- **Brainstem pathways are responsible for regulating muscle tone** and **for orienting the eyes, head and body with respect to vestibular, somatic, auditory and visual sensory information.**



Local Spinal Cord and Brainstem Circuits

- Lower motor neurons send their axons out of the brainstem to **innervate muscles of the head and neck and** to innervate **muscles of the body.**
- Local circuit neurons **receive sensory inputs** as well as descending projections **from higher centers** and **provide the coordination between different muscle groups** essential for organized movement
  - they are the major source of synaptic input to the lower motor neurons.



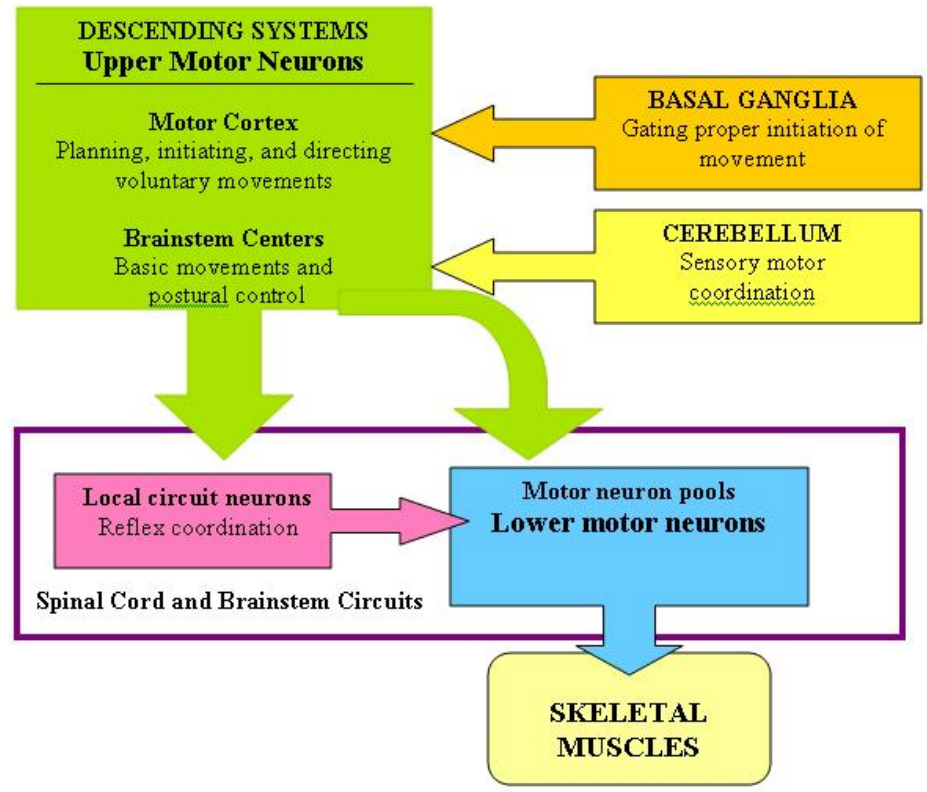
Local Spinal Cord and Brainstem Circuits

Cerebellum

- **detects motor error** which are differences between an intended movement and the movement actually performed, and **provides input to upper motor neurons.**

Basal Ganglia

- **suppress unwanted movement** and primes upper motor neuron circuits for movement initiation.



DESCENDING MODULATORY PATHWAYS (UPPER MOTOR NEURONS)

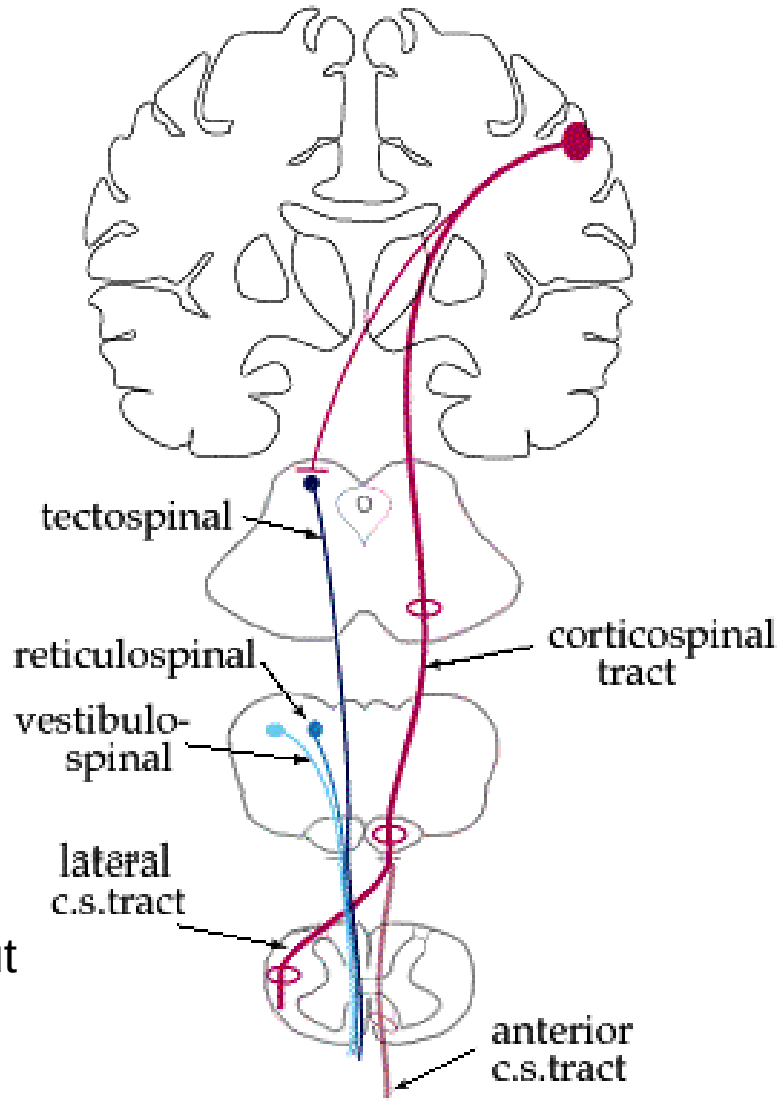
Upper motor neurons influence the spinal cord by two routes:

1) direct projections to the spinal cord (ventral corticospinal tract; lateral corticospinal tract)

2) indirect projections to brainstem centers that in turn project to the spinal cord (e.g. corticoreticulospinal tract)

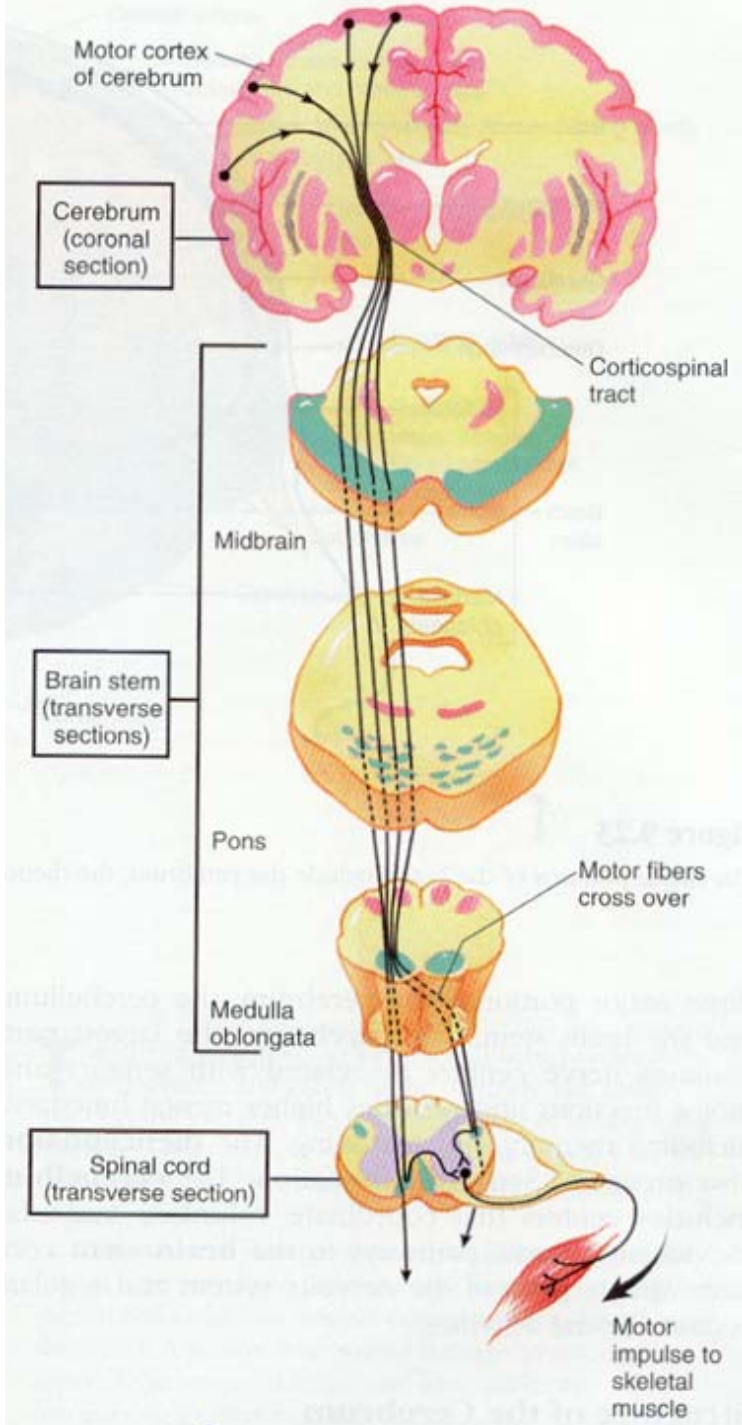
Spinal Motor Tracts

- There are several pathways which innervate the alpha-motor neurons.
- can be roughly grouped into the
  - **voluntary** (direct projection) motion pathways
    - **lateral** and **anterior corticospinal** systems (pyramidal tracts)
  - **postural** pathways.(extrapyramidal, indirect projection)
    - pathways do not originate in cortex
    - their function is to maintain an upright posture against gravity
    - There are three principal pathways in humans: the **vestibulospinal**, **tectospinal**, and **reticulospinal** pathways.
    - **rubrospinal** system (from the red nucleus) is also sometimes included, but in humans it may be insignificant.



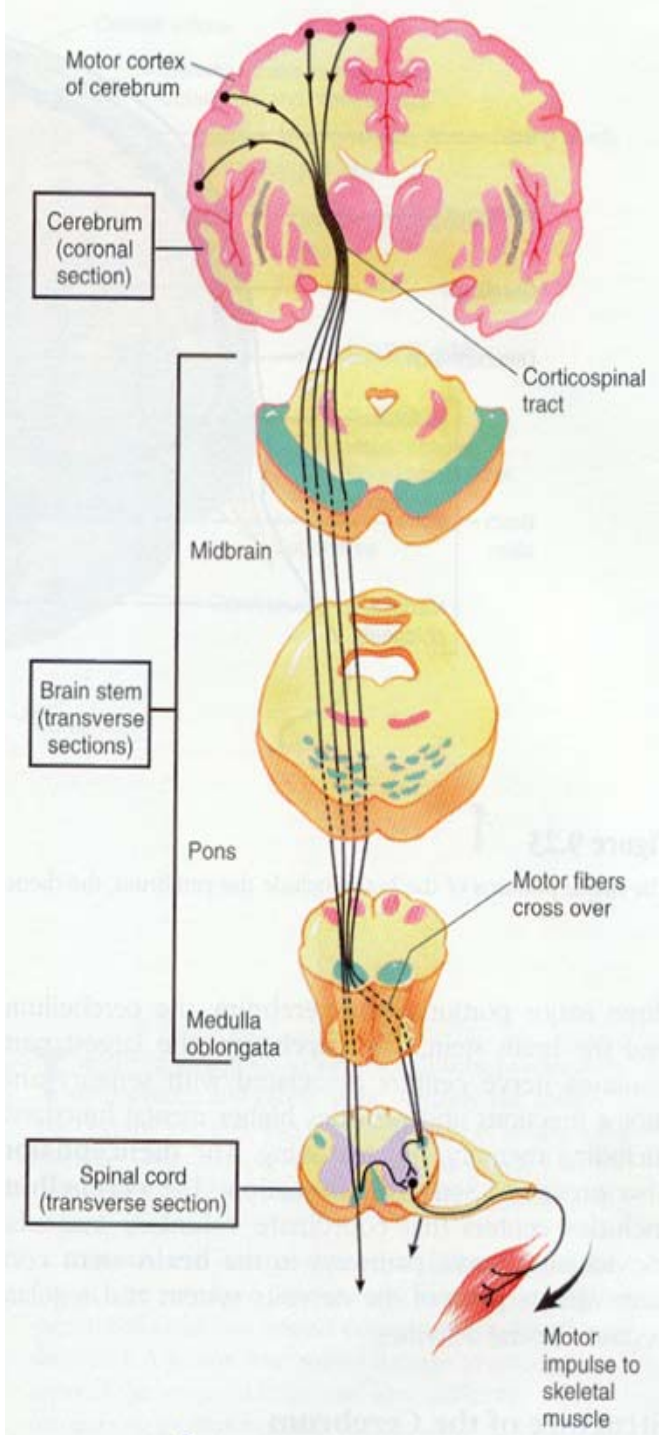
Pyramidal Motor System (Corticospinal Tract)

- controls all our voluntary movement via a two-neuron system:
  - upper motor neurons in the primary motor cortex
    - upper motor neuron axon extends all the way from the brain down to the spinal cord, a distance 1-3 feet or more
  - lower motor neurons in the anterior horn of the spinal cord.
    - axon extends from the spinal cord to the skeletal muscles of the arms or legs, a distance 4-5 feet in very tall people.



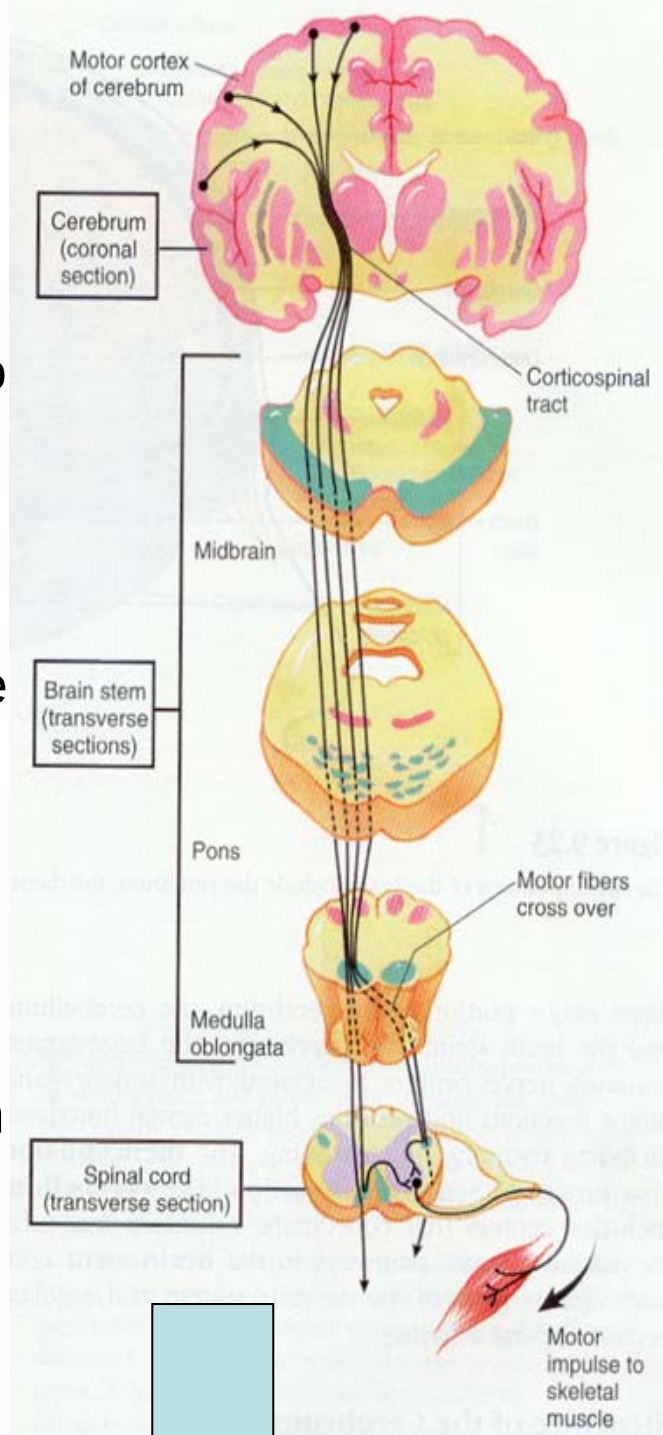
Corticospinal Tract

- Upper motor neurons pass from the motor cortex
- through the internal capsule of the forebrain, cerebral peduncle at the base of the midbrain,
- scatter through the base of the pons
- coalesce on the ventral surface of the medulla to form the medullary pyramids.



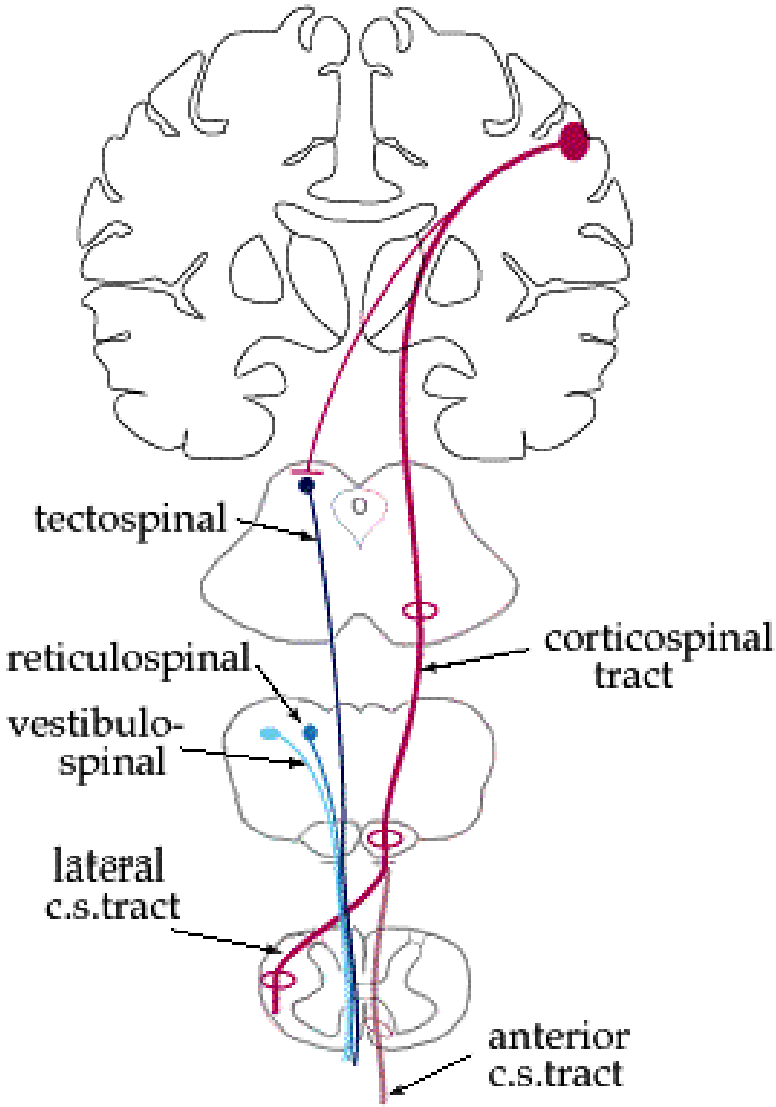
Corticospinal Tract

- 80 - 90 % of corticospinal tract axons cross to the other side in the distal medulla forming the **lateral corticospinal tract.**
- The pyramidal decussation separates the medulla,above, from the spinal cord, below.
- The **Ventral Corticospinal tract** contains the axons from the 10-20% of neurons whose axons did not cross to the other side at the pyramidal decussation.
- The upper motor neuron axons then synapse on lower motor neurons in the Anterior horn of the spinal cord.
- The axons of these lower motor neurons then exit the spinal cord via the Ventral root. Damage to LMN's causes flaccid paralysis.



Postural Pathway Damage

- Understand that the postural pathways are controlled to some degree by the cortical structures
  - You must be able to turn off selective postural systems to accomplish other movements.
- **Decorticate posture**- cortical input is damaged close to its source, (i.e., in the internal capsule)
- Since they are getting no input from cortex, the postural pathways **flex the upper limbs and extend the lower limb by default.**
- If the damage cuts off not just cortical input but all input from the entire cerebrum, such as with a massive brainstem injury, the result is a **decerebrate** posture.
  - In the decerebrate position all four limbs are extended and somewhat turned in (pronated).
  - his sort of injury is much more serious tha an injury of the internal capsule; the prognosis is usually very poor.



Voluntary Motor Pathway Damage

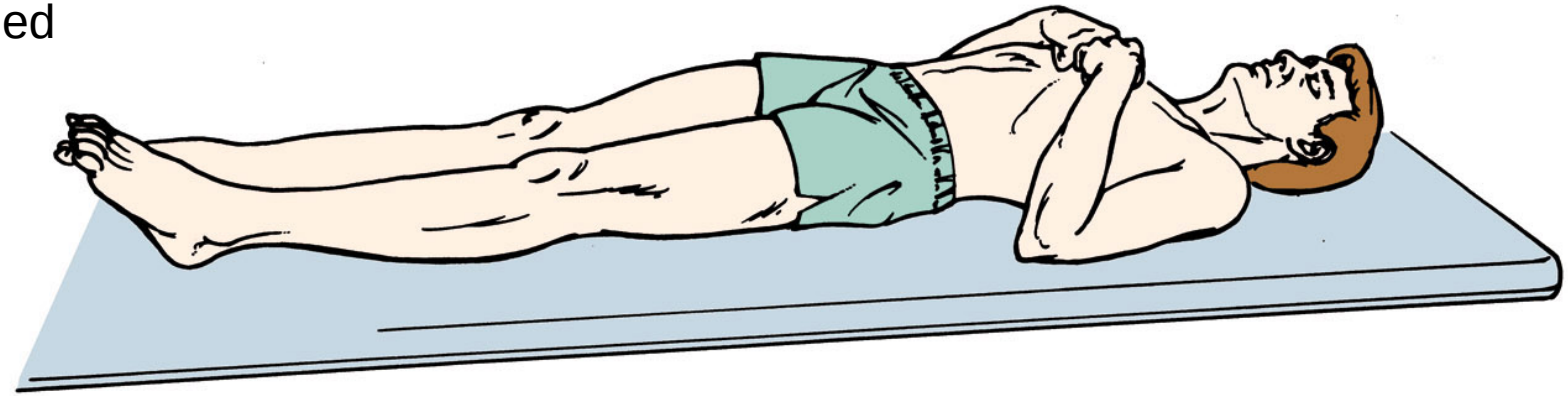
- Just as the postural pathways have a "mind of their own" when cortical control is cut off, the spine can also produce some weird behaviors when the corticospinal tract is damaged.
- All of the spinal reflexes are local - all of the cells involved are contained within one or two segments, and cortex is not necessary.
- Therefore **reflexes** would **still be present in a transected spinal cord.**
- However, the **cortex normally keeps a tight rein on reflexive behavior**, so that it doesn't interfere with normal movements. ***When the cortex is cut off, the spinal cord becomes hyperreflexic.*** All of the **normal reflexes become exaggerated**, and some new ones appear.
  - Ex: **Babinski sign**

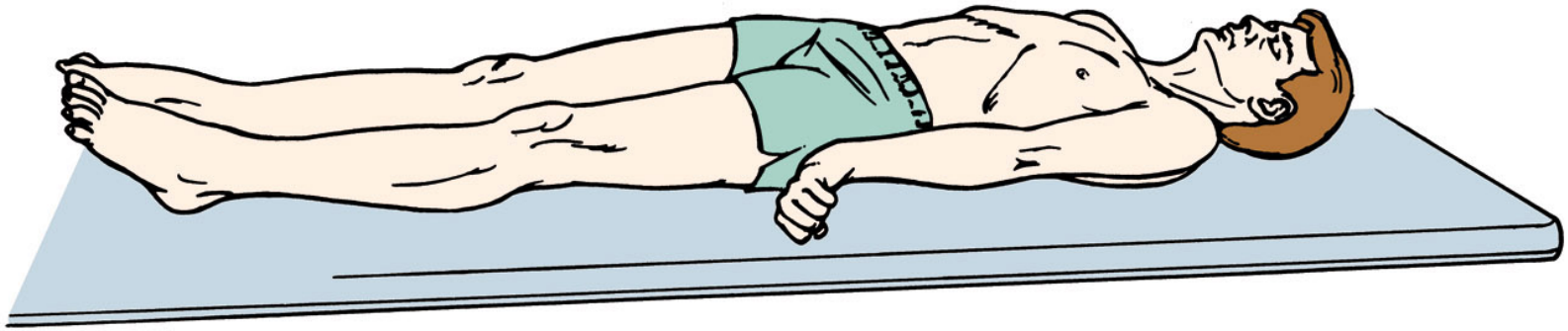
Babinski sign

- stroking the lateral sole of your foot with a sharp object would normally make your toes curl downward.
- In a patient with corticospinal damage (also called upper motor neuron damage), the big toe would lift up and the toes would fan out.
- always pathological (with the exception of very young infants).

Decorticate Posturing

Flexor posturing arms flexed and legs extended



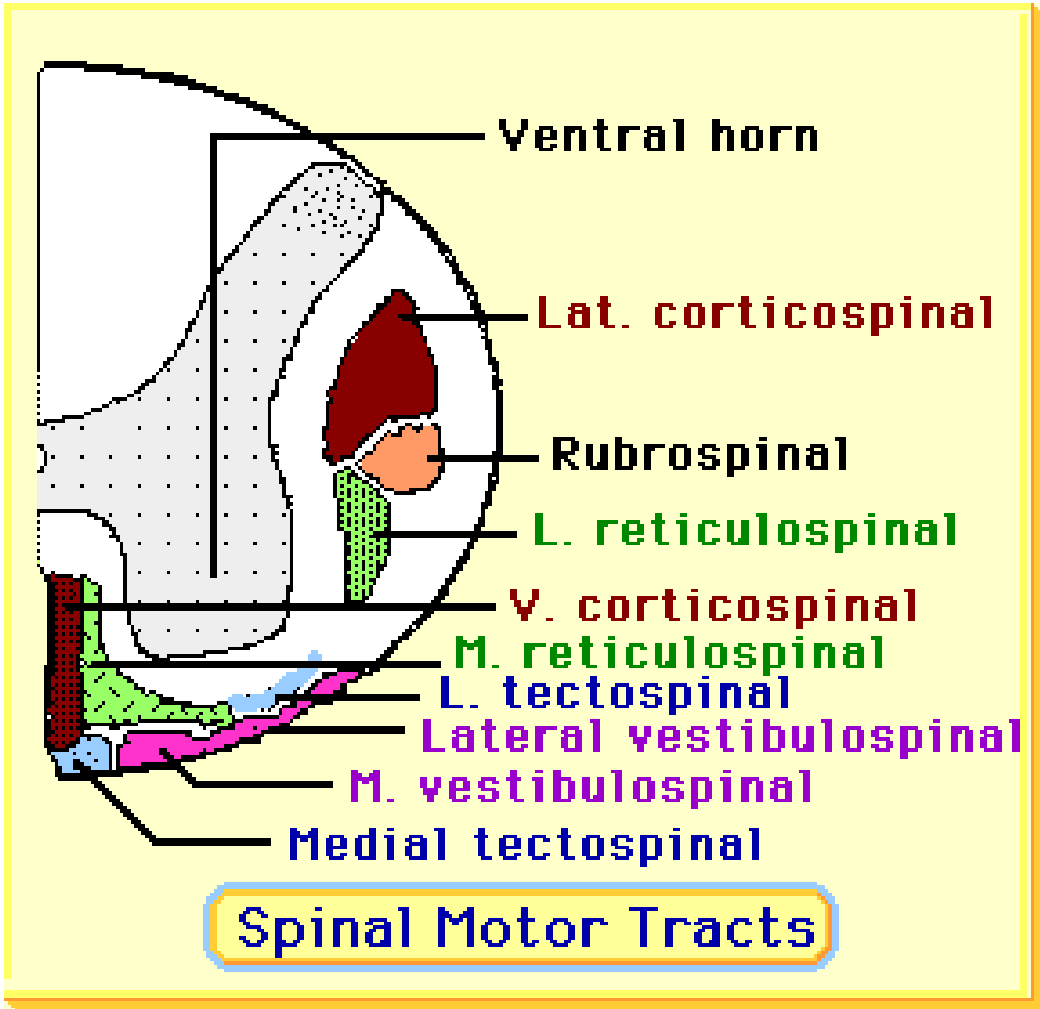


Extensor posturing arms and legs extended

Decerebrate Posturing

Extrapyramidal Tracts

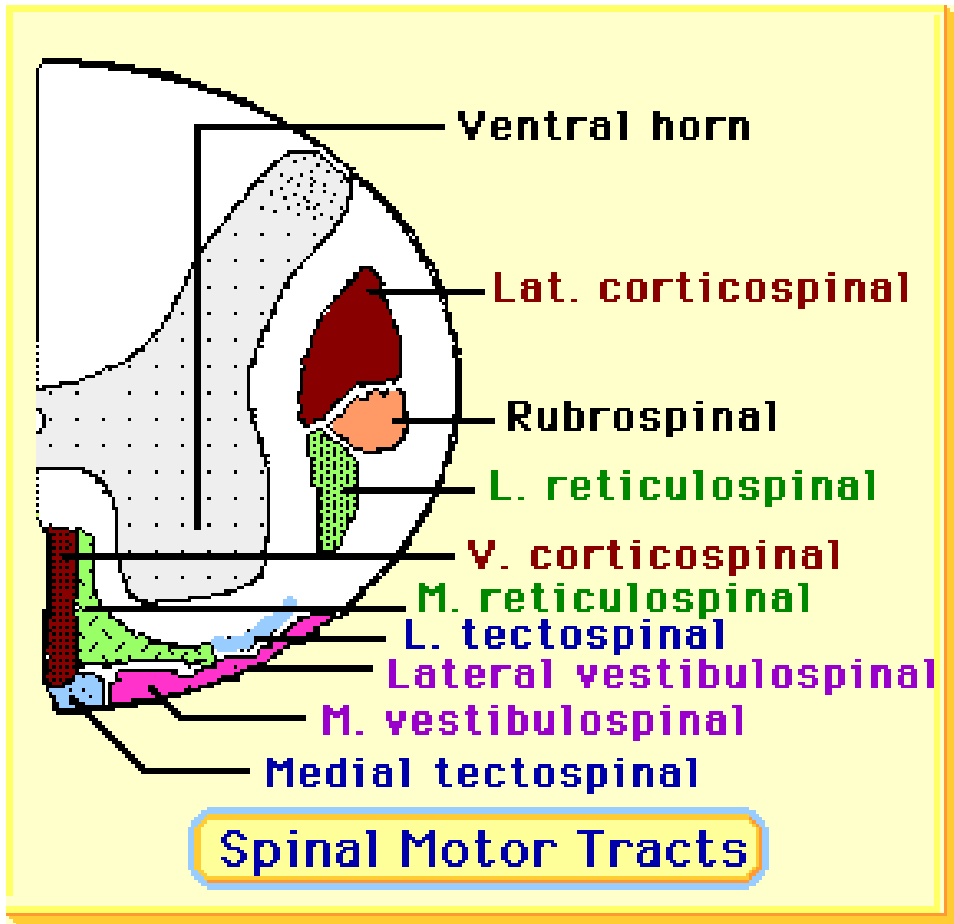
- **Tectospinal tracts** are found in cervical cord segments only.
- begins in the midbrain retion called the tectum
- axons synapse onto motor horn cells innervating muscles that move the head
- **involved in reflex movements of head in response to visual and auditory stimuli**



Extrapyramidal Tracts

Lateral & Medial Reticulospinal tract

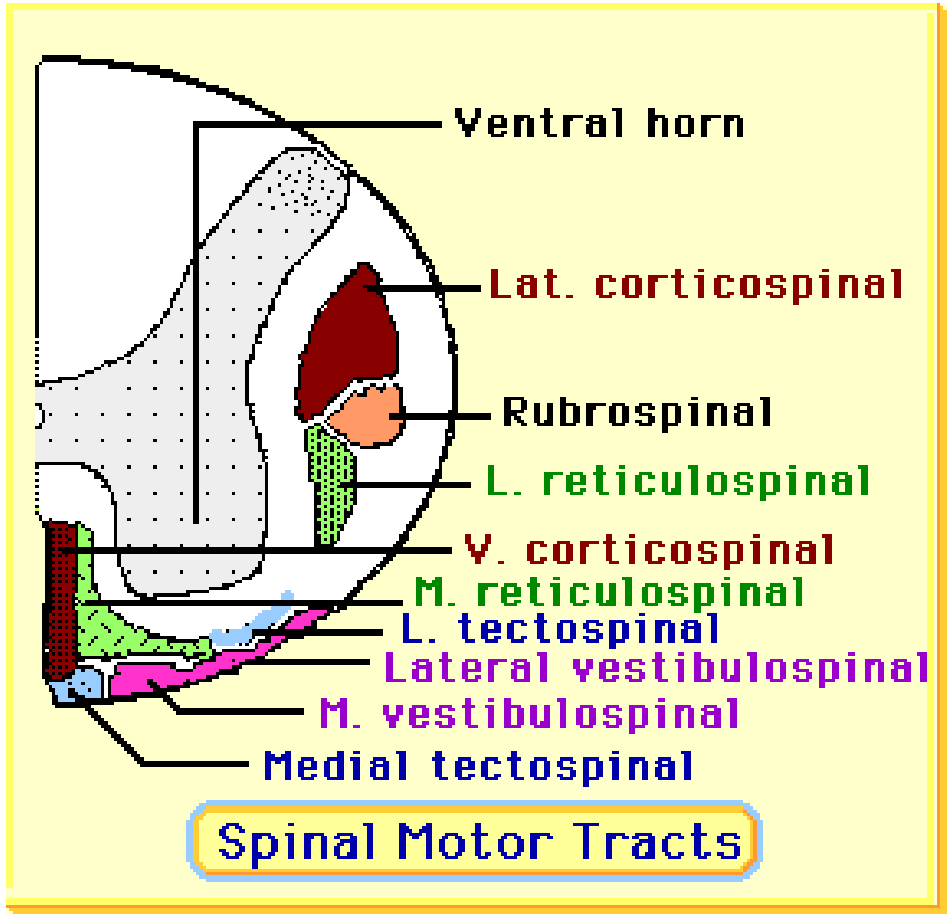
- tract originates in the reticular formation of the brainstem
- involved in the muscles that control posture and balance
- also contain descending analgesic pathways that reduce transmission of pain signals to the brain
- the principal function of the reticulospinal tracts is **to provide efferent signals to the lateral horn of the gray matter--the autonomic pre-ganglionic fibers.** This includes both the sympathetic outflow as well as the sacral parasympathetics.



Extrapyramidal Tracts

Vestibulospinal tract

- Cells are **located in vestibular nuclei of the medulla**, and they synapse onto lower motor horn circuits of locomotor and trunk musculature that receives impulses for balance from the inner ear
  - based on saccular, utricular and semicircular duct sensation--inner ear and sense of balance/acceleration.
- controls limb muscles that maintain balance and posture



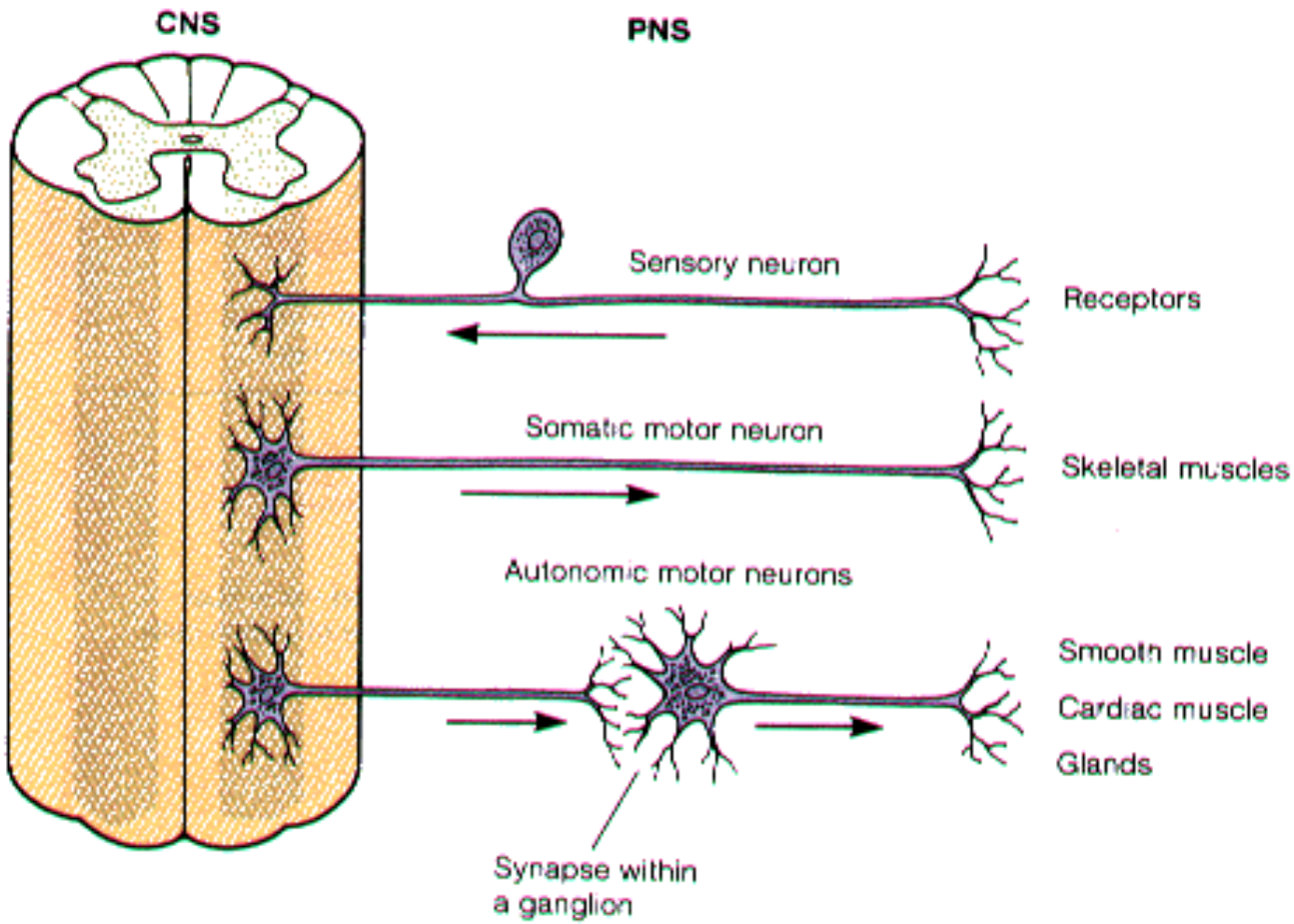
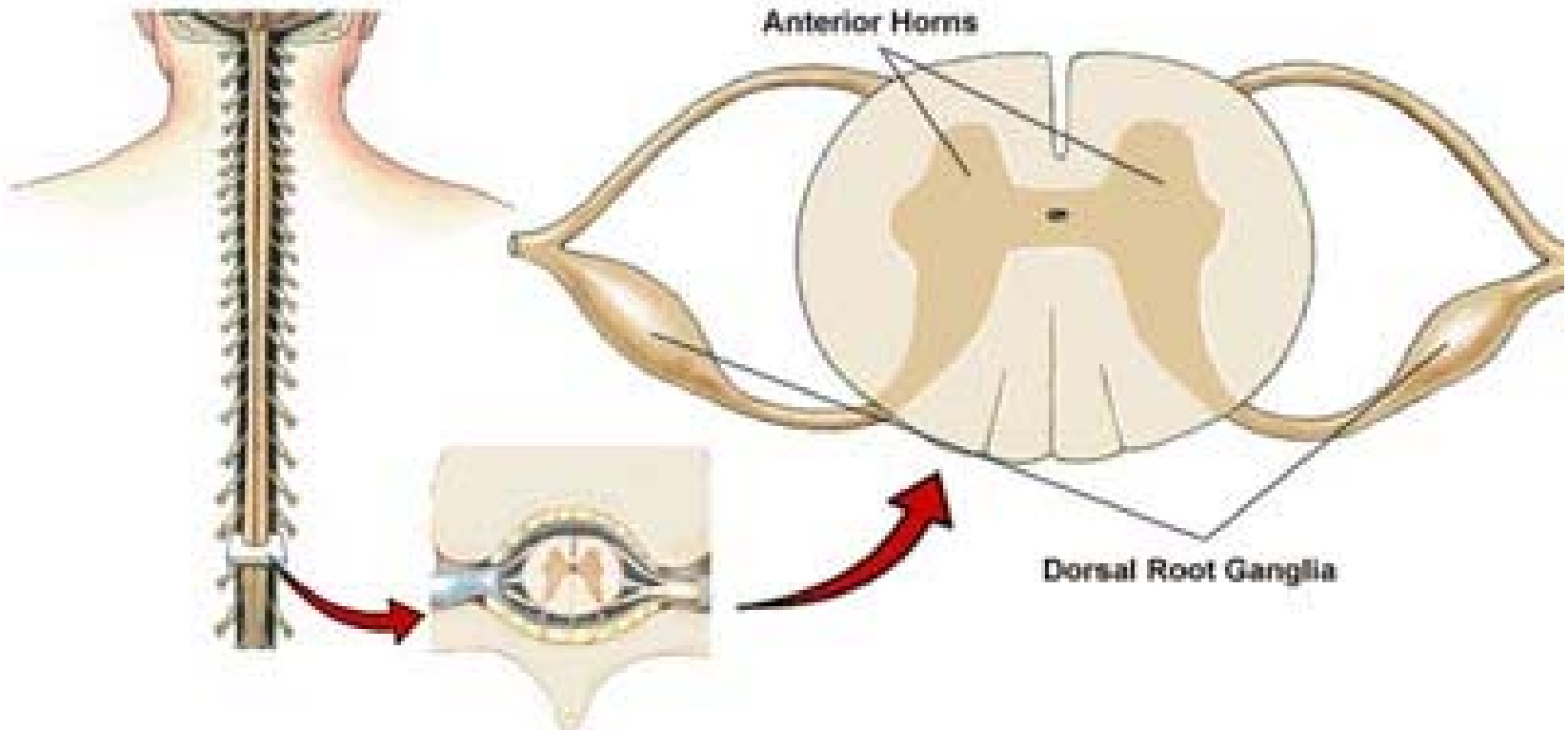
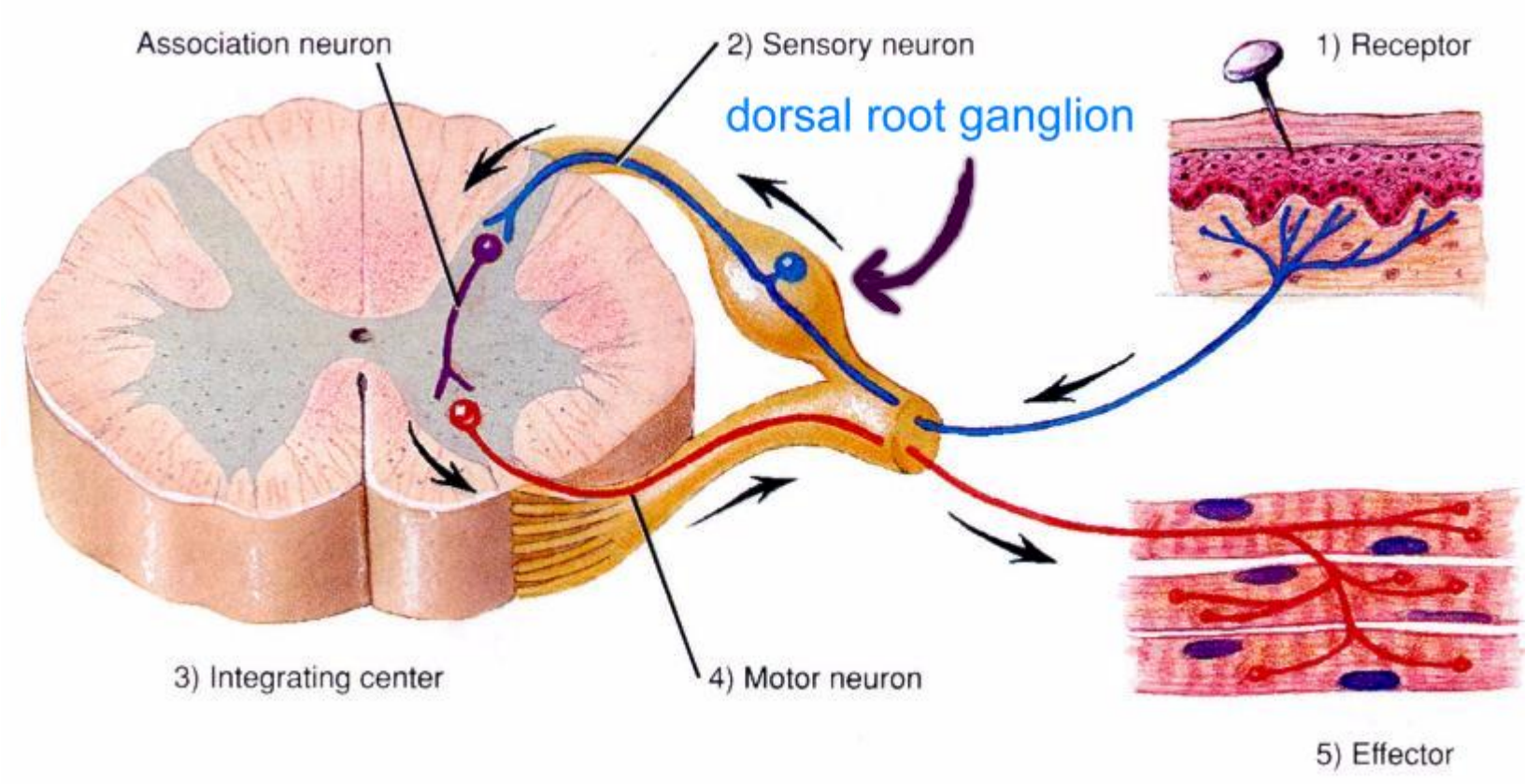

CNS
PNS
Sensory neuron
Receptors
Somatic motor neuron
Skeletal muscles
Autonomic motor neurons
Smooth muscle
Cardiac muscle
Glands
Synapse within
a ganglion

Figure F-6: Dorsal Root Ganglion & Anterior Horn



The dorsal root ganglion transmits *sensory* information while the anterior horn directs *motor* neurons.


Association neuron
2) Sensory neuron
dorsal root ganglion
1) Receptor
3) Integrating center
4) Motor neuron
5) Effector

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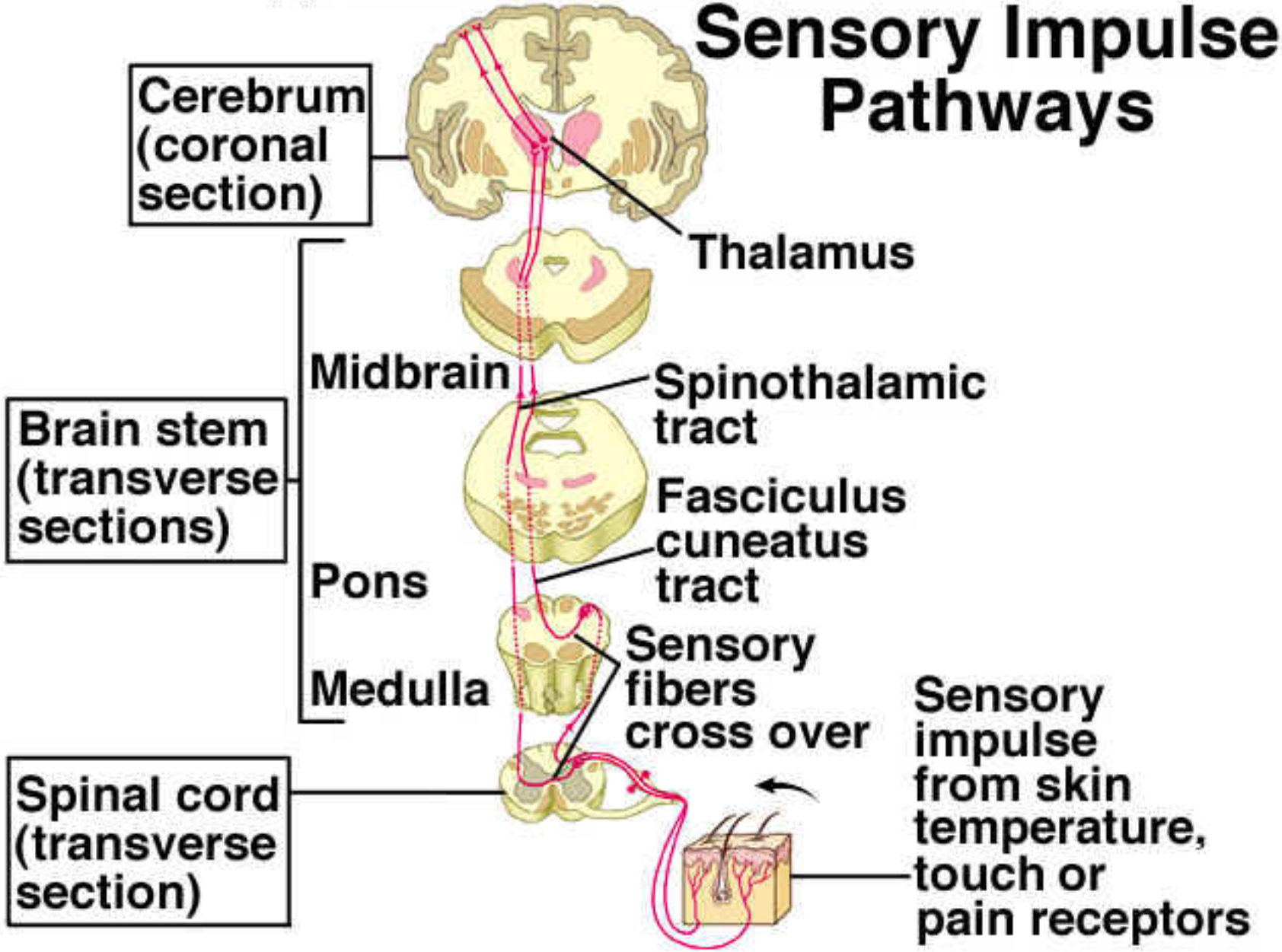
Sensory Impulse Pathways



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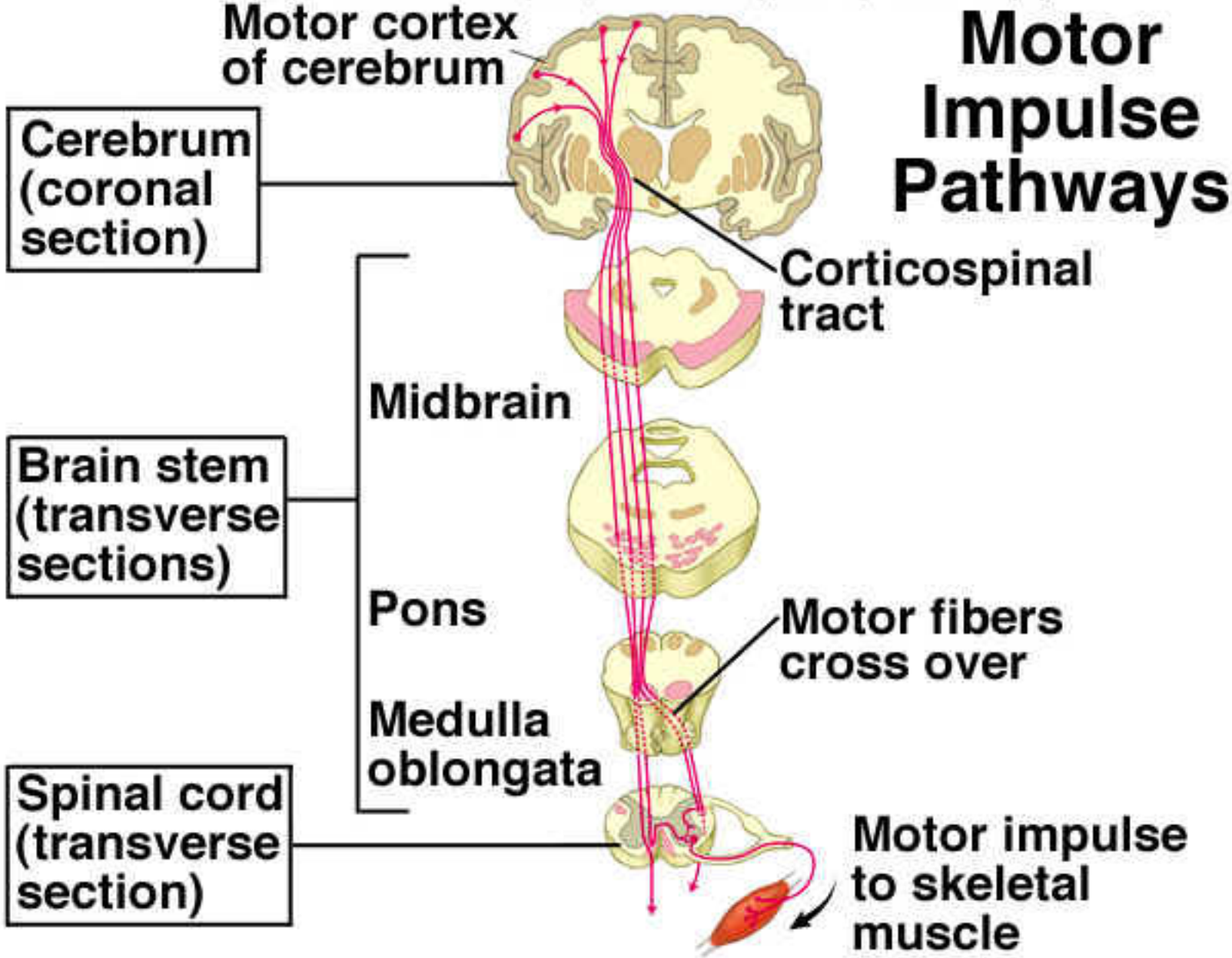
Motor Impulse Pathways



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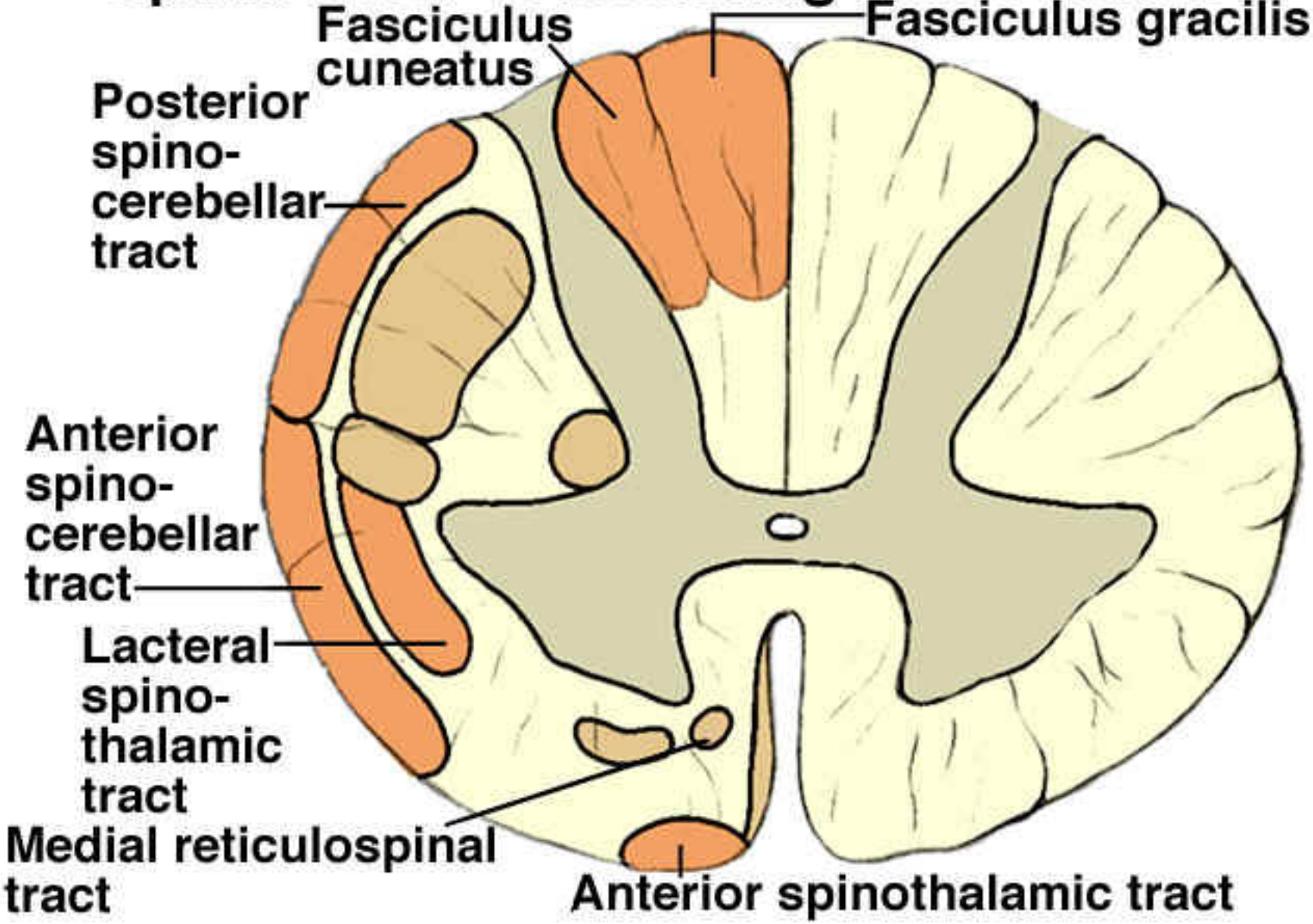
Spinal Cord—Ascending Nerve Tracts



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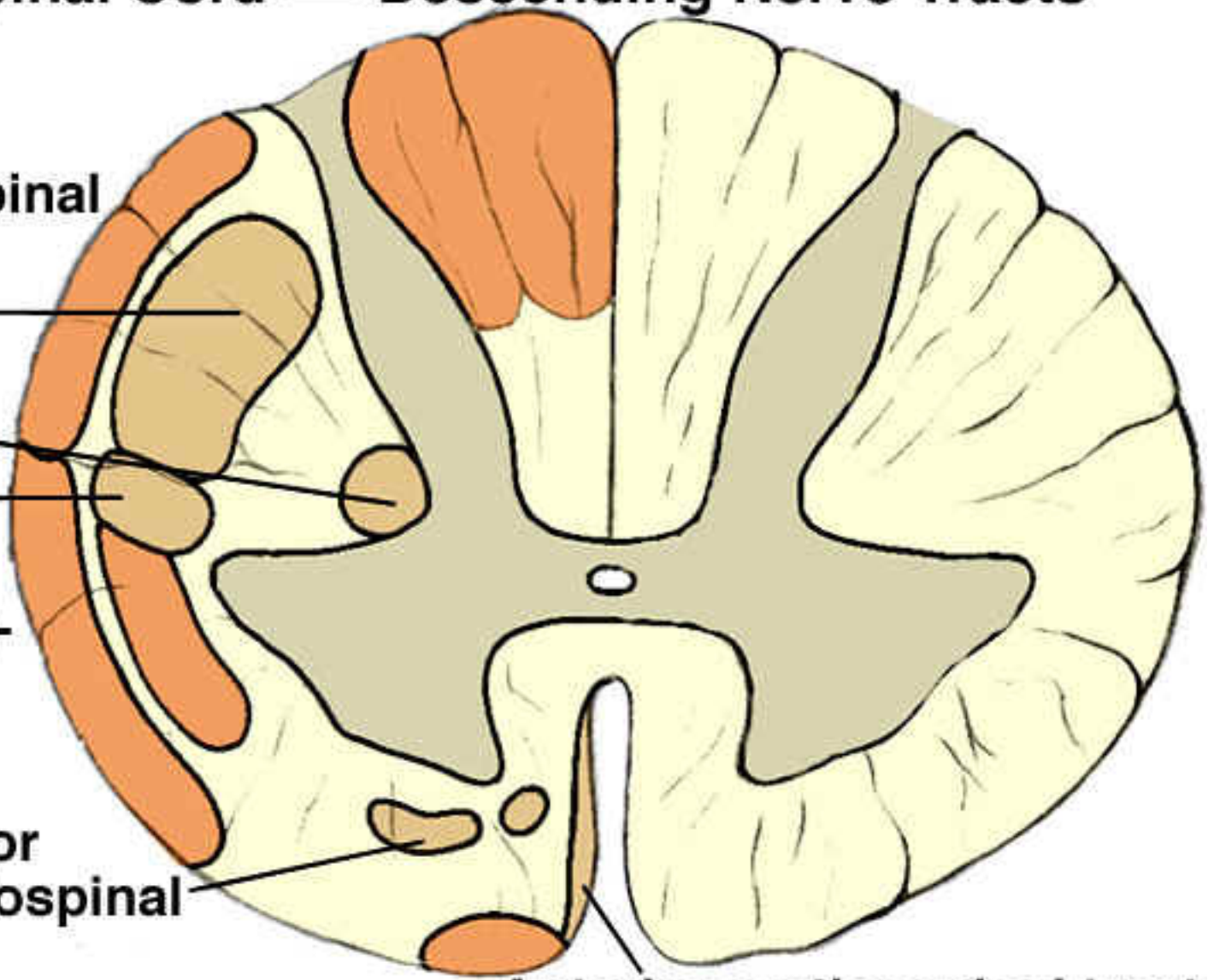
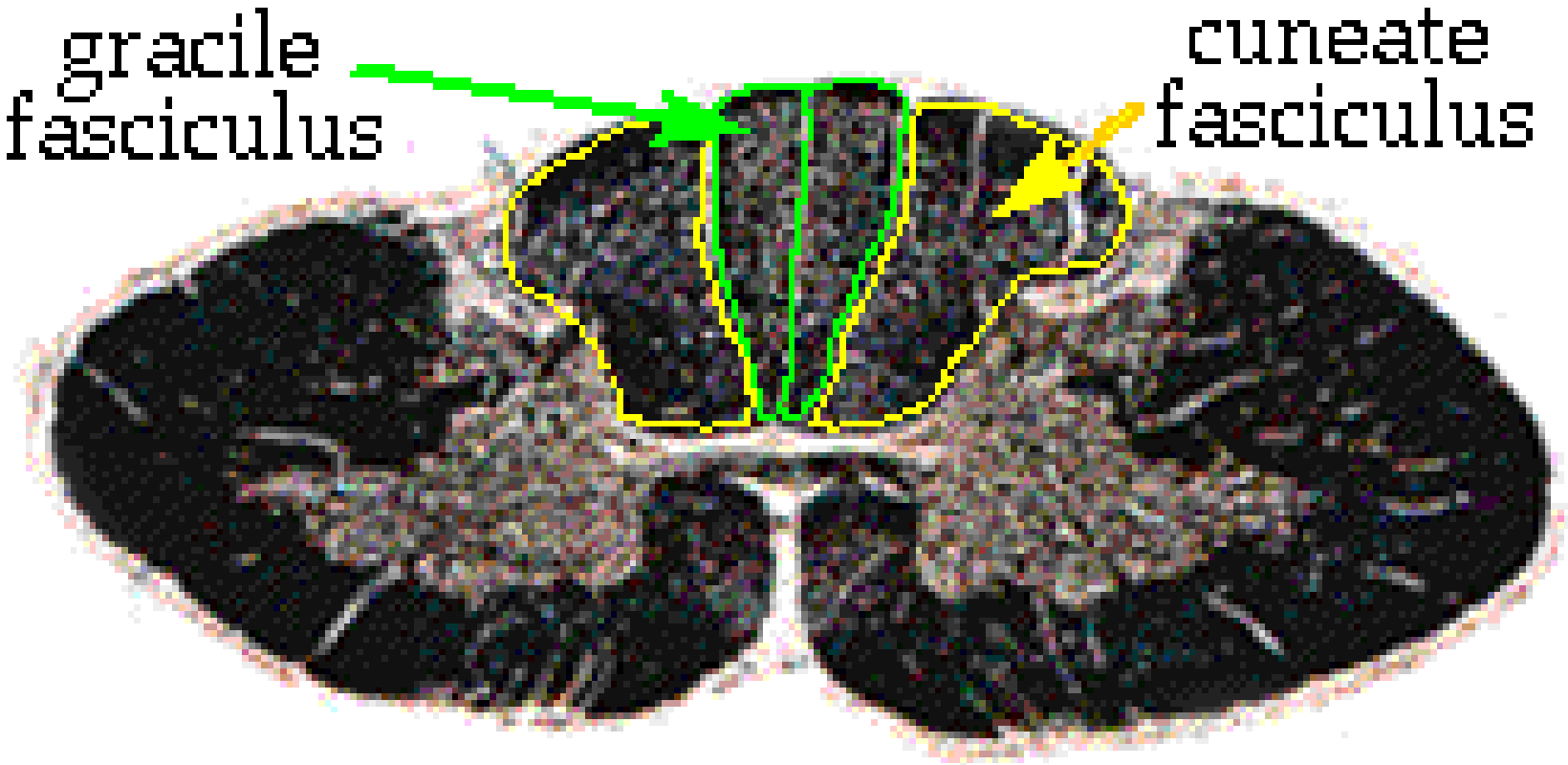
Spinal Cord — Descending Nerve Tracts




gracile
fasciculus
cuneate
fasciculus

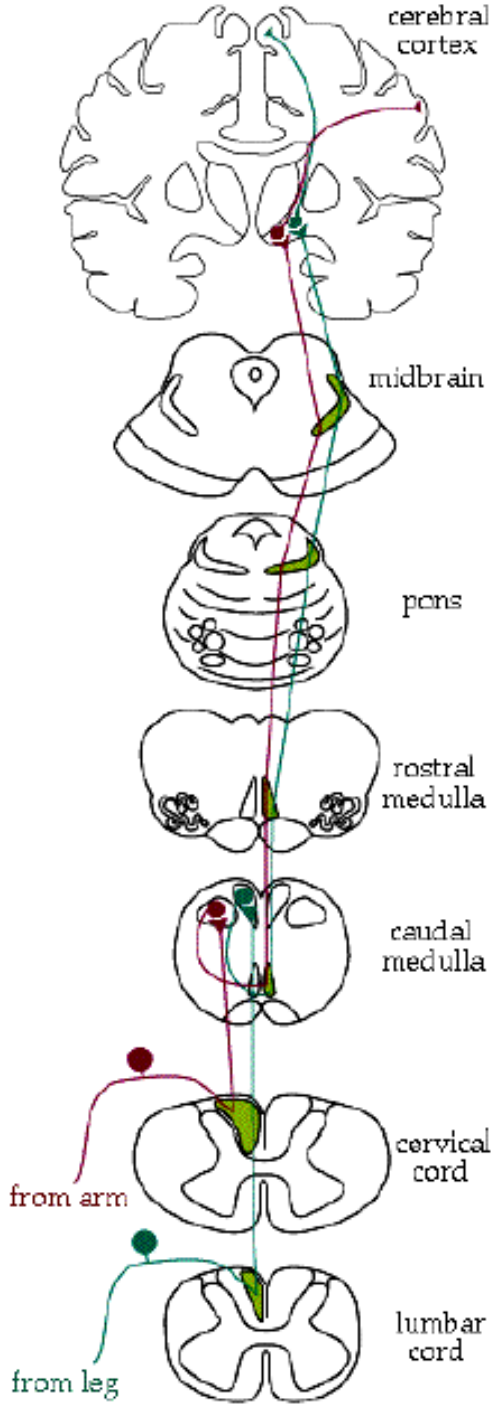

cerebral cortex
midbrain
pons
rostral medulla
caudal medulla
cervical cord
lumbar cord
from arm
from leg

Figure 14.3
Origins and terminations of (a) the corticospinal tract and (b) the rubrospinal tract. These components of the lateral pathways control fine movements of the arms and fingers.

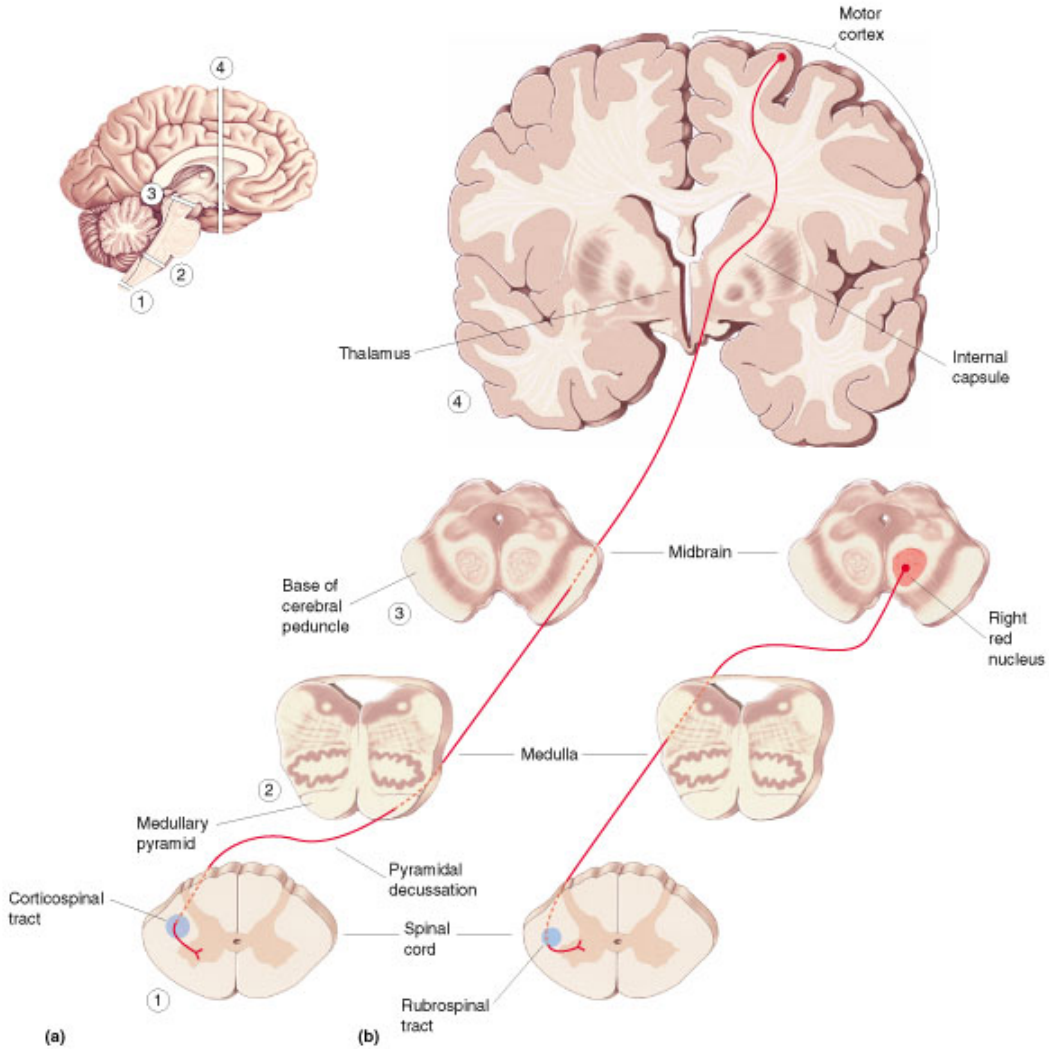


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Figure 14.4
Origins and terminations of (a) the vestibulospinal tract and (b) the tectospinal tract. These components of the ventromedial pathway control the posture of the head and neck.

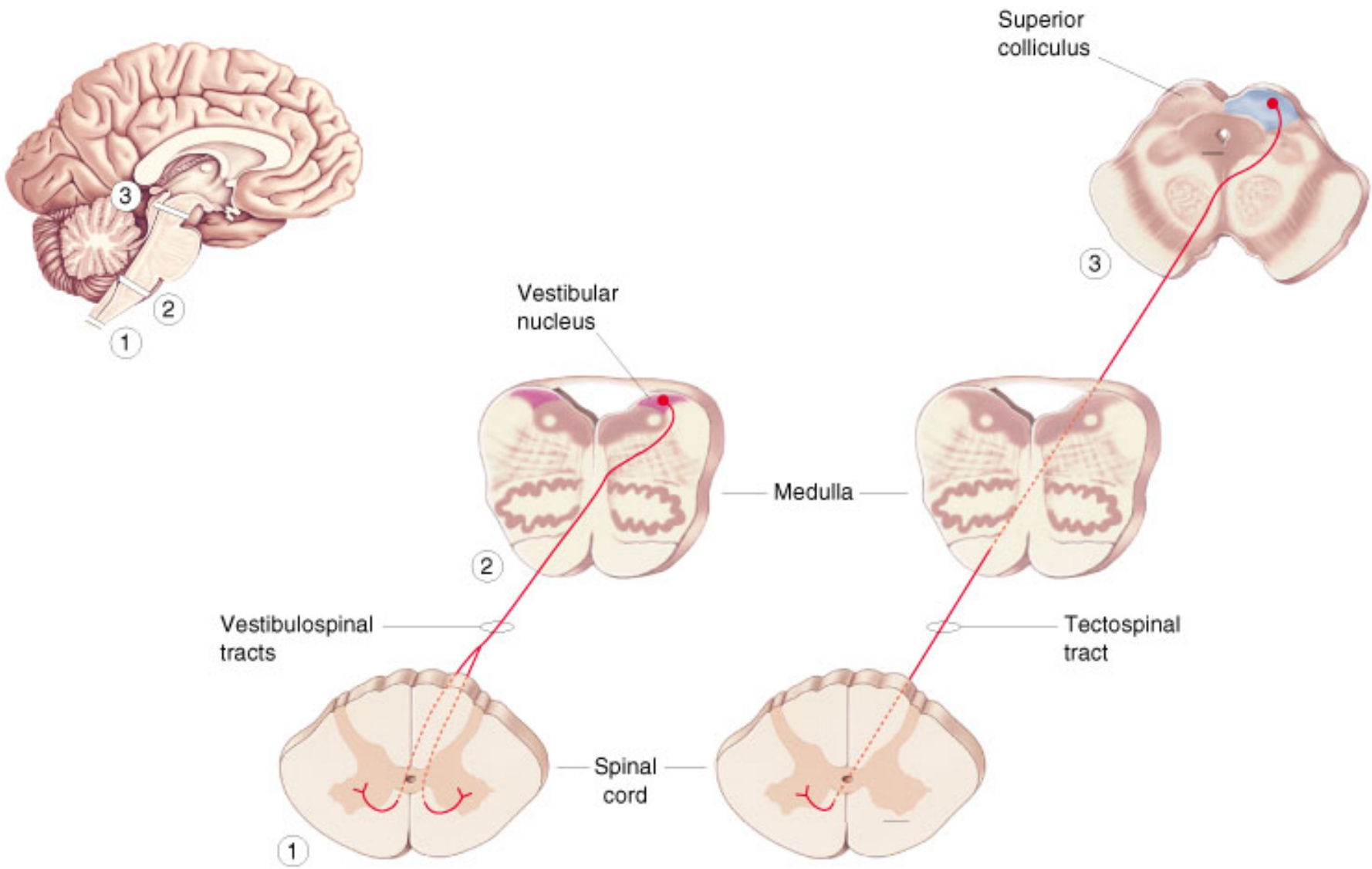

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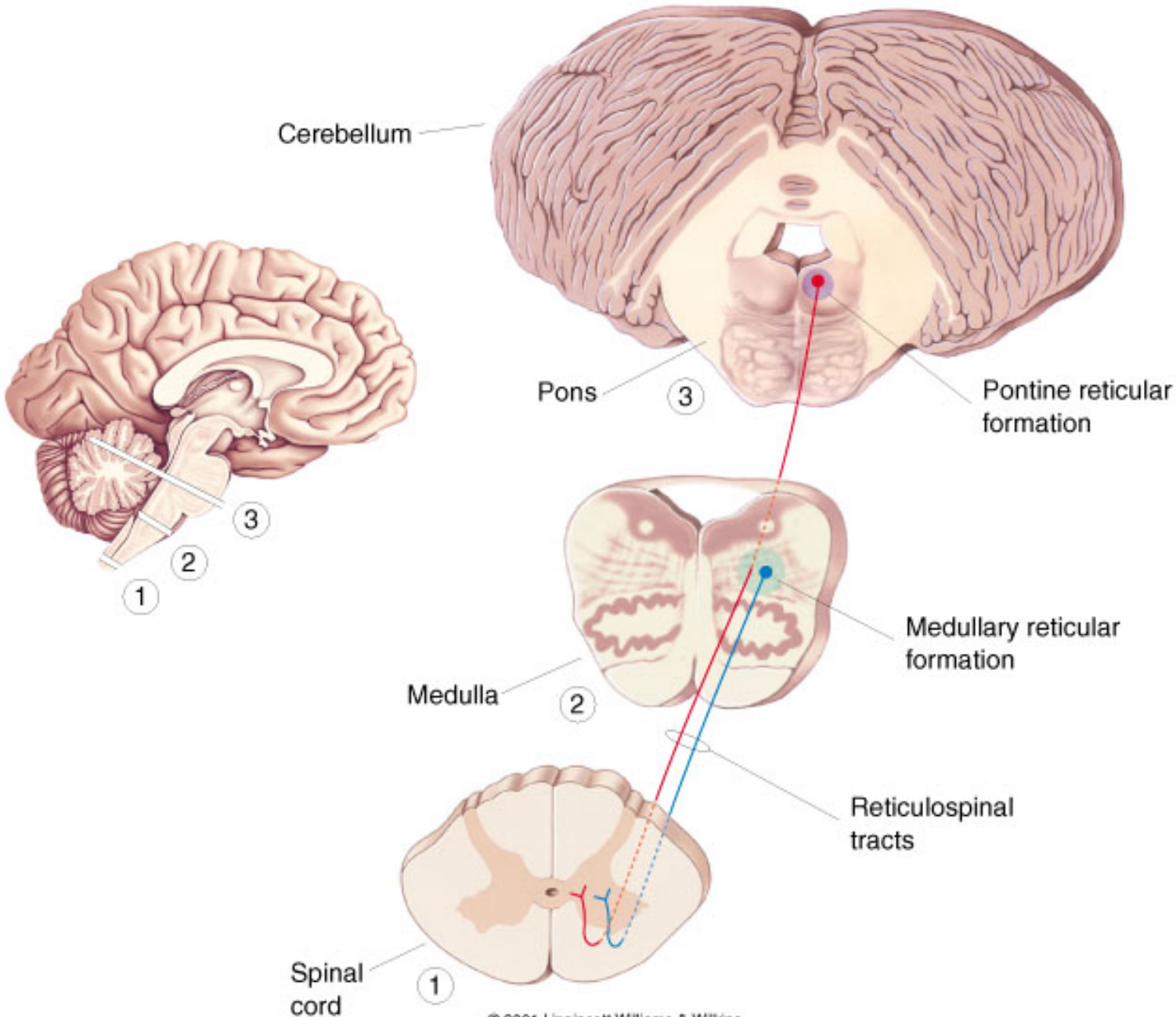
Figure 14.5
The pontine (medial) and medullary (lateral) reticulospinal tracts. These components of the ventromedial pathway control posture of the trunk and the antigravity muscles of the limbs.



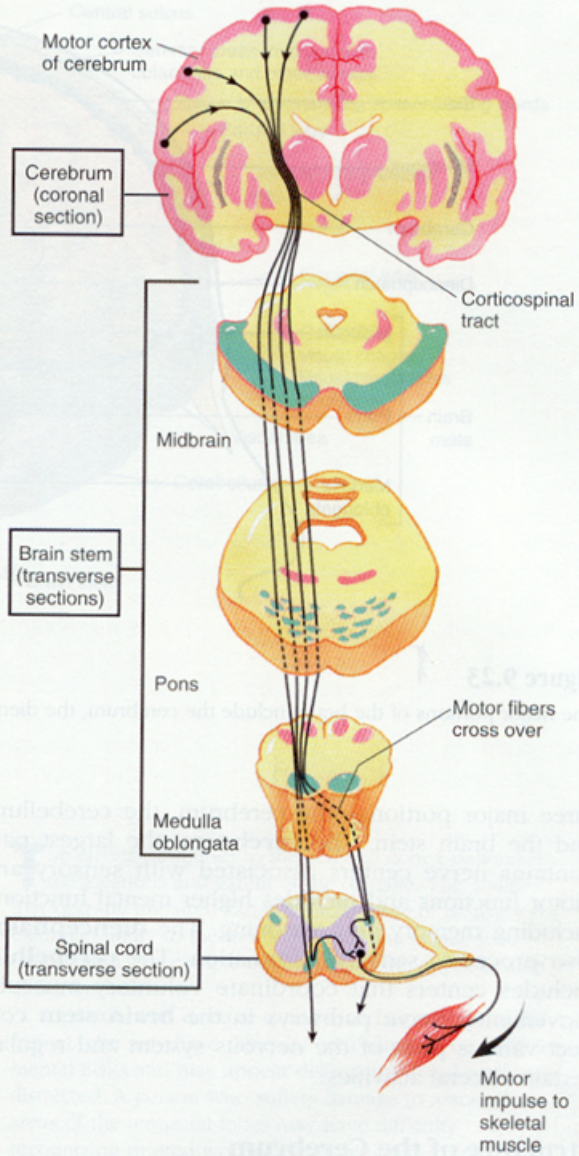
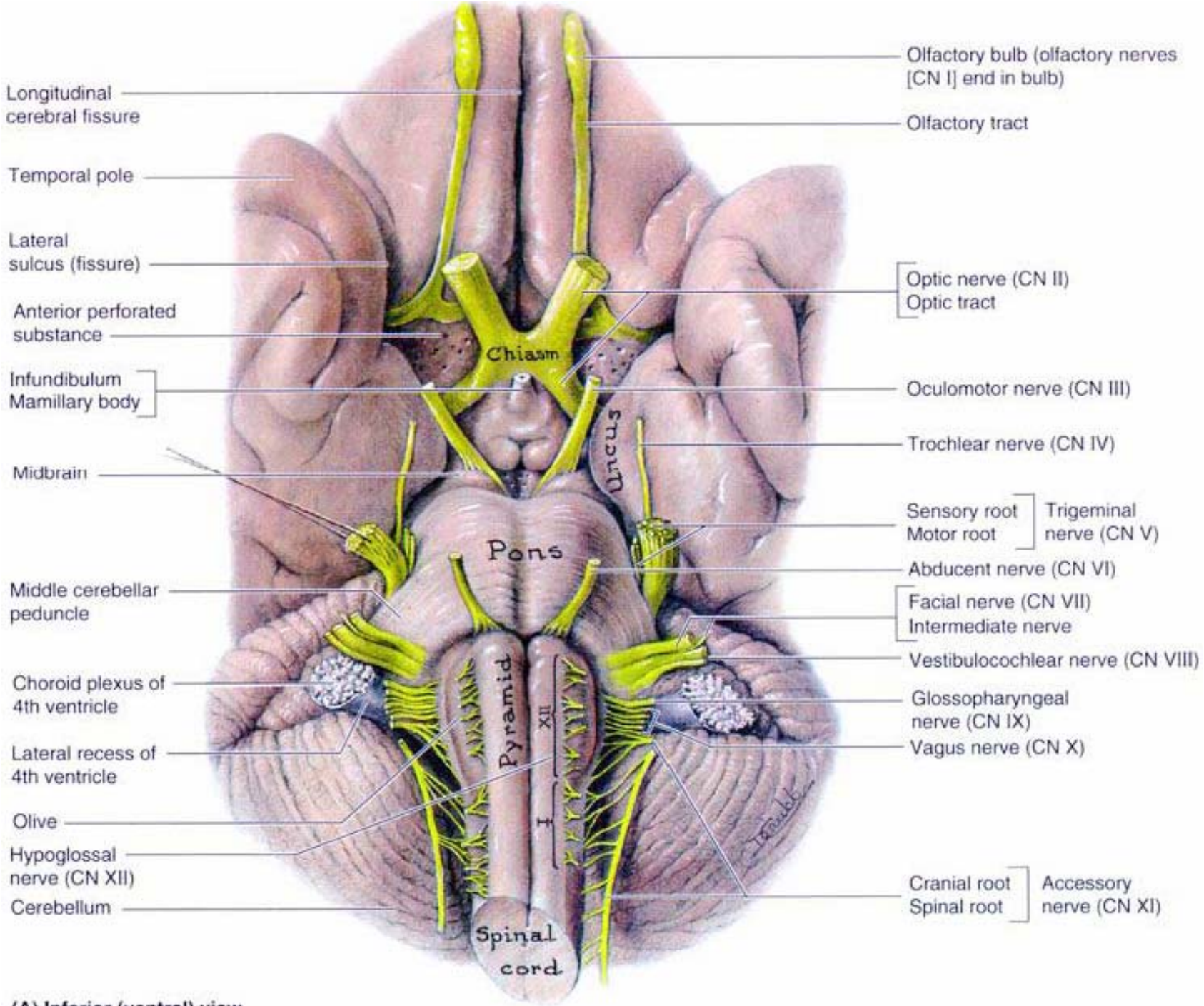


Figure 9.22

Motor fibers of the corticospinal tract begin in the cerebral cortex, cross over in the medulla oblongata, and descend in the spinal cord. There, they synapse with neurons whose fibers lead to the spinal nerves that supply skeletal muscles.



(A) Inferior (ventral) view

TABLE 12.4 Cranial Nerves: Sensory and Motor Functions *(Part 1)*

NERVE	NAME	FUNCTIONAL CATEGORIES	FUNCTIONS
CN I	Olfactory nerve	Special somatic sensory	Olfaction
CN II	Optic nerve	Special somatic sensory	Vision
CN III	Oculomotor nerve	Somatic motor	Levator palpebrae superior, and all extraocular muscles, except for superior oblique and lateral rectus
		Parasympathetic	Parasympathetics to pupil constrictor and ciliary muscles for near vision
CN IV	Trochlear nerve	Somatic motor	Superior oblique muscle; causes depression and intorsion of the eye
CN V	Trigeminal nerve	General somatic sensory	Sensations of touch, pain, temperature, joint position, and vibration for the face, mouth, anterior two-thirds of tongue, nasal sinuses, and meninges
		Branchial motor	Muscles of mastication and tensor tympani muscle
CN VI	Abducens nerve	Somatic motor	Lateral rectus muscle; causes abduction of the eye
CN VII	Facial nerve	Branchial motor	Muscles of facial expression, stapedius muscle, and part of digastric muscle
		Parasympathetic	Parasympathetics to lacrimal glands, and to submaxillary, submandibular, and all other salivary glands except parotid
		Visceral sensory (special)	Taste from anterior two-thirds of tongue
		General somatic sensory	Sensation from a small region near the external auditory meatus
CN VIII	Vestibulocochlear nerve	Special somatic sensory	Hearing and vestibular sensation

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TABLE 12.4 Cranial Nerves: Sensory and Motor Functions *(Part 2)*

NERVE	NAME	FUNCTIONAL CATEGORIES	FUNCTIONS
CN IX	Glossopharyngeal nerve	Branchial motor	Stylopharyngeus muscle
		Parasympathetic	Parasympathetics to parotid gland
		General somatic sensory	Sensation from middle ear, region near the external auditory meatus, pharynx, and posterior one-third of tongue
		Visceral sensory (special)	Taste from posterior one-third of tongue
		Visceral sensory (general)	Chemo- and baroreceptors of carotid body
CN X	Vagus nerve	Branchial motor	Pharyngeal muscles (swallowing) and laryngeal muscles (voice box)
		Parasympathetic	Parasympathetics to heart, lungs, and digestive tract down to the splenic flexure
		General somatic sensory	Sensation from pharynx, meninges, and a small region near the external auditory meatus
		Visceral sensory (special)	Taste from epiglottis and pharynx
		Visceral sensory (general)	Chemo- and baroreceptors of the aortic arch
CN XI	Spinal accessory nerve	Branchial motor	Sternomastoid and upper part of trapezius muscle
CN XII	Hypoglossal nerve	Somatic motor	Intrinsic muscles of the tongue

Note: See Table 12.3 and Figure 12.5 for nuclei.

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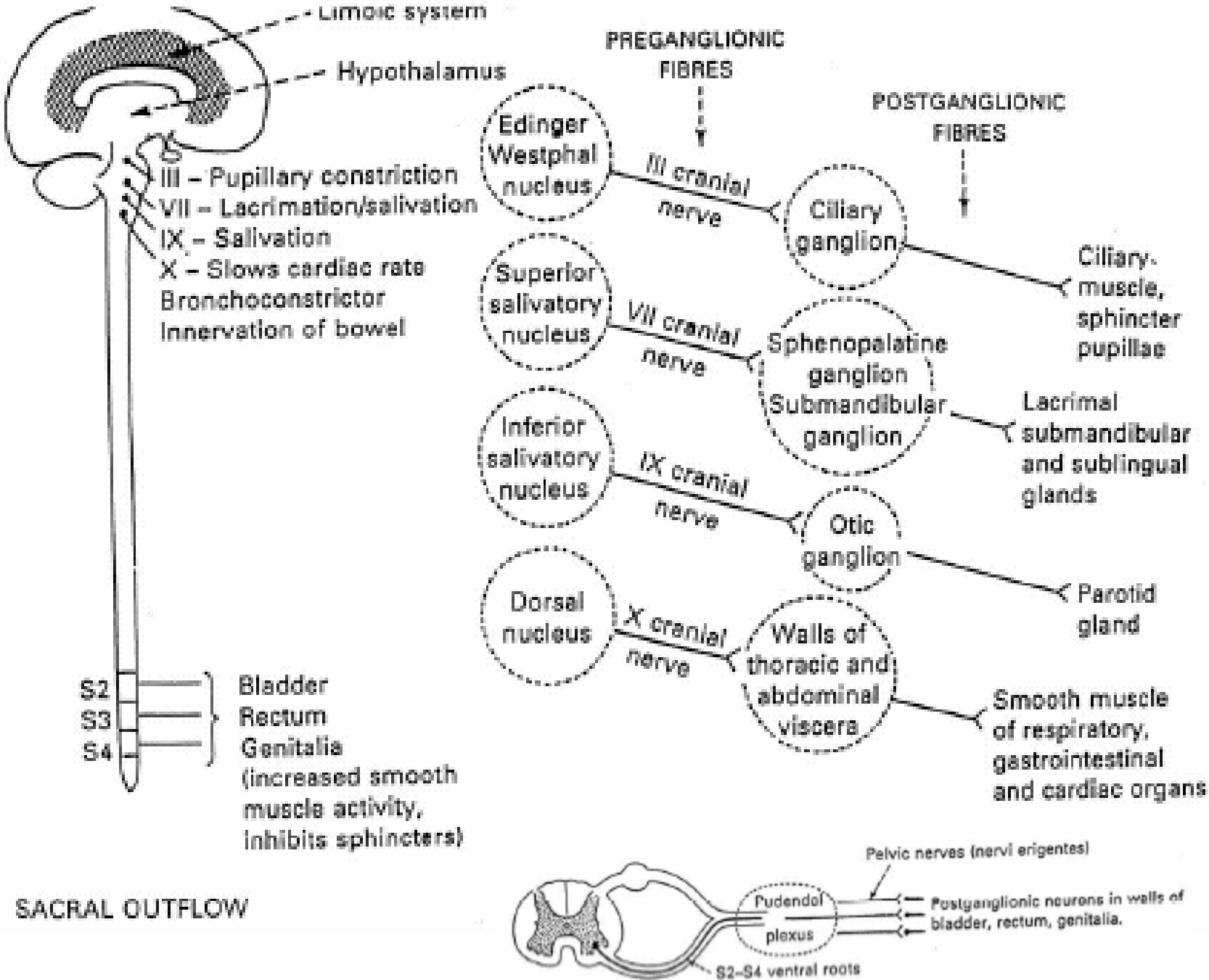
Number	Name	Function	Type
I	Olfactory Nerve	Smell	Sensory
II	Optic Nerve	Vision	Sensory
III	Oculomotor Nerve	Eye movement; pupil dilation	Motor
IV	Trochlear Nerve	Eye movement	Motor
V	Trigeminal Nerve	Somatosensory information (touch, pain) from the face and head; muscles for chewing.	Mixt
VI	Abducens Nerve	Eye movement	Motor
VII	Facial Nerve	Taste (anterior 2/3 of tongue); somatosensory information from ear; controls muscles used in facial expression.	Mixt
VIII	Vestibulocochlear Nerve	Hearing; balance	Sensory
IX	Glossopharyngeal Nerve	Taste (posterior 1/3 of tongue); Somatosensory information from tongue, tonsil, pharynx; controls some muscles used in swallowing.	Mixt
X	Vagus Nerve	Sensory, motor and autonomic functions of viscera (glands, digestion, heartrate)	Mixt
XI	Spinal Accessory Nerve	Controls muscles used in head movement.	Motor
XII	Hypoglossal Nerve	Controls muscles of tongue	Motor



SACRAL OUTFLOW

Cranial Nerves 1-6

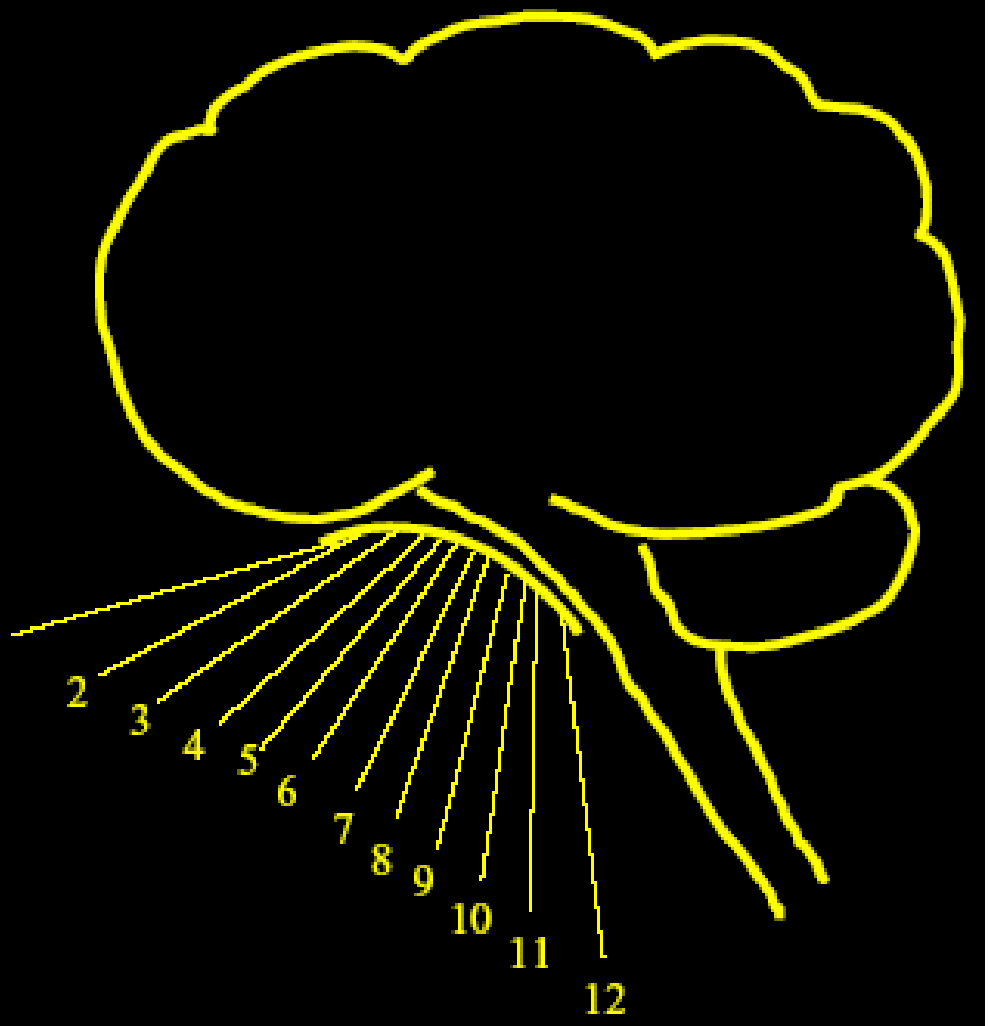
Cranial nerve	Function	Symptom of damage
Olfactory (I)	Smell	Anosmia
Optic (II)	Vision	Blindness
Oculomotor (III)	Eye movement	Eye deviates down & out Loss of pupil reflexes
Trochlear (IV)	Eye movement	Diplopia, lateral deviation of eye
Trigeminal (V)	Facial sensation Mastication	Facial aneasthesia Loss of pain sensation Insignificant Weakness/loss of mastication
Abducens (VI)	Eye movement	Medial eye deviation

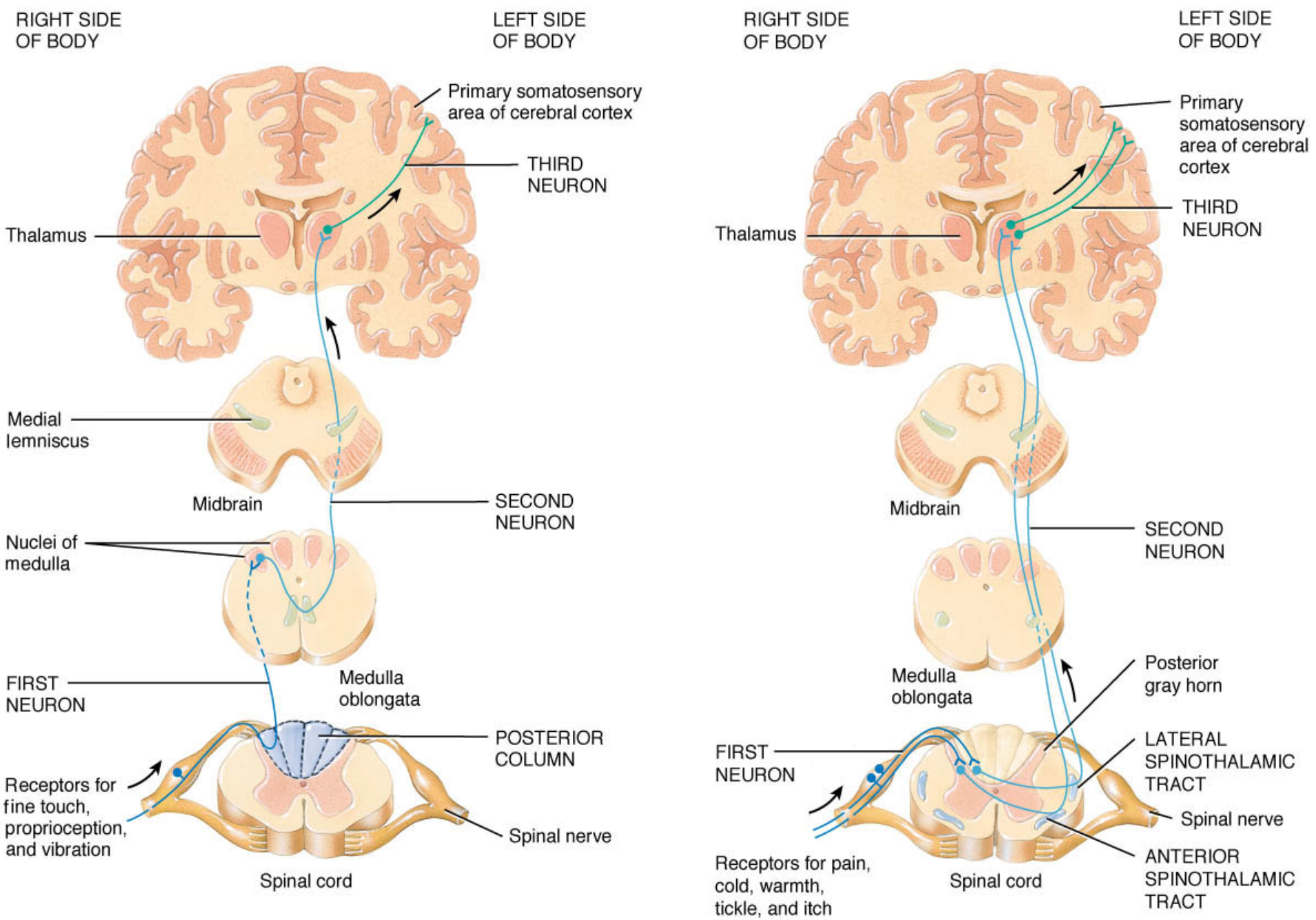
Cranial Nerves 7-12

Cranial nerve	Function	Symptom of damage
Facial (VII)	Facial expression, Taste,Salivation, tears	Paralysis of facial muscles. Loss of taste. Dry mouth
Auditory (VIII)	Balance, Hearing	Vertigo, disequilibrium, loss of hearing
Glossopharyngeal (IX)	Taste, Salivation, innervation of pharynx	Loss of taste, loss of gag reflex
Vagus (X)	Swallowing & talking, Cardiac, GI tract, respiration, Taste	Dysphagia & hoarseness of voice
Spinal Accessory (XI)	Pharynx/larynx muscles, Neck & shoulder movement	Head turning weakness
Hypoglossal (XII)	Tongue movement	Atrophy of tongue muscles, deviation on protrusion

The Cranial Nerves

On	I.	Olfactory
Old	II.	Optic
Olympus'	III.	Occulomotor
Towering	IV.	Trochlear
Top	V.	Trigeminal
A	VI.	Abducens
Finn	VII.	Facial
And	VIII.	Acoustic
German	IX.	Glossopharyngeal
Viewed	X.	Vagus
Some	XI.	Spinal Accessory
Hops	XII.	Hypoglossal





(a) Posterior column–medial lemniscus pathway

(b) Anterolateral (spinothalamic) pathways

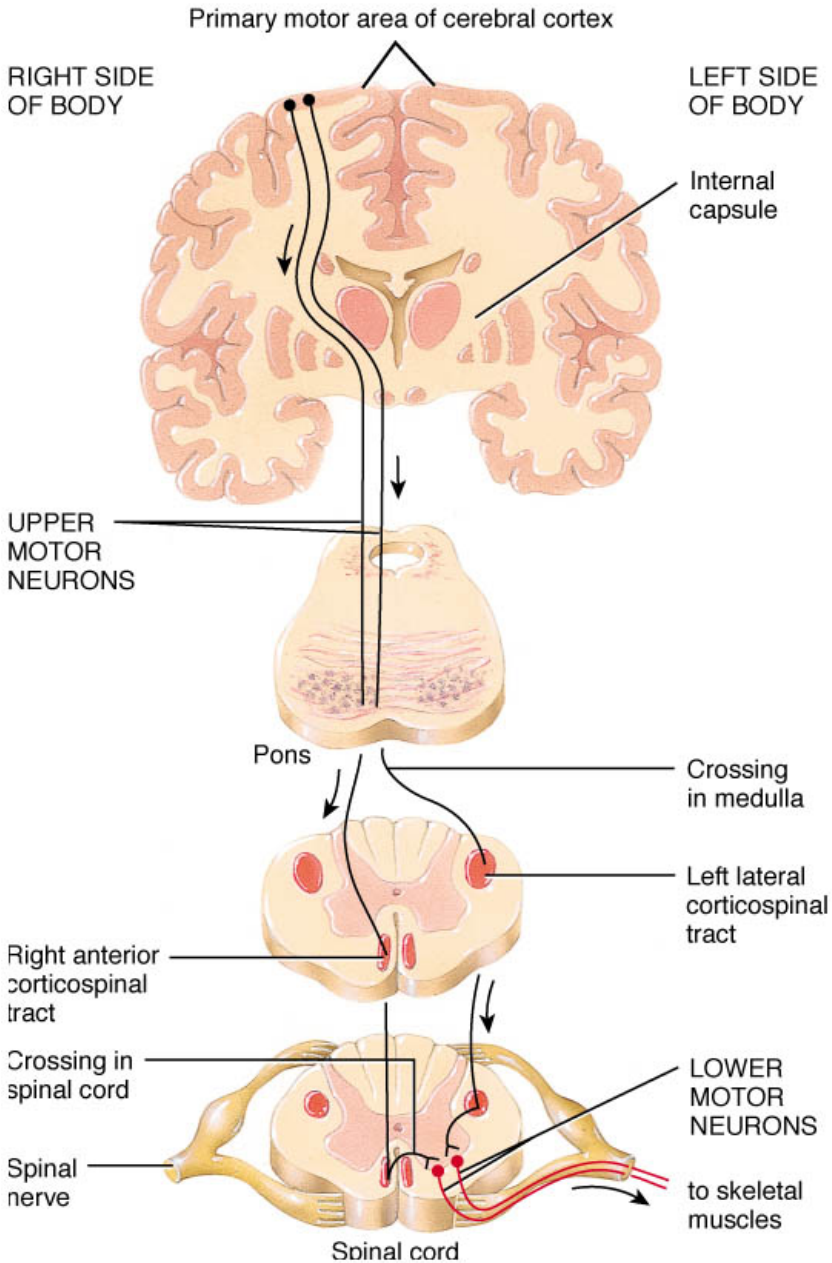
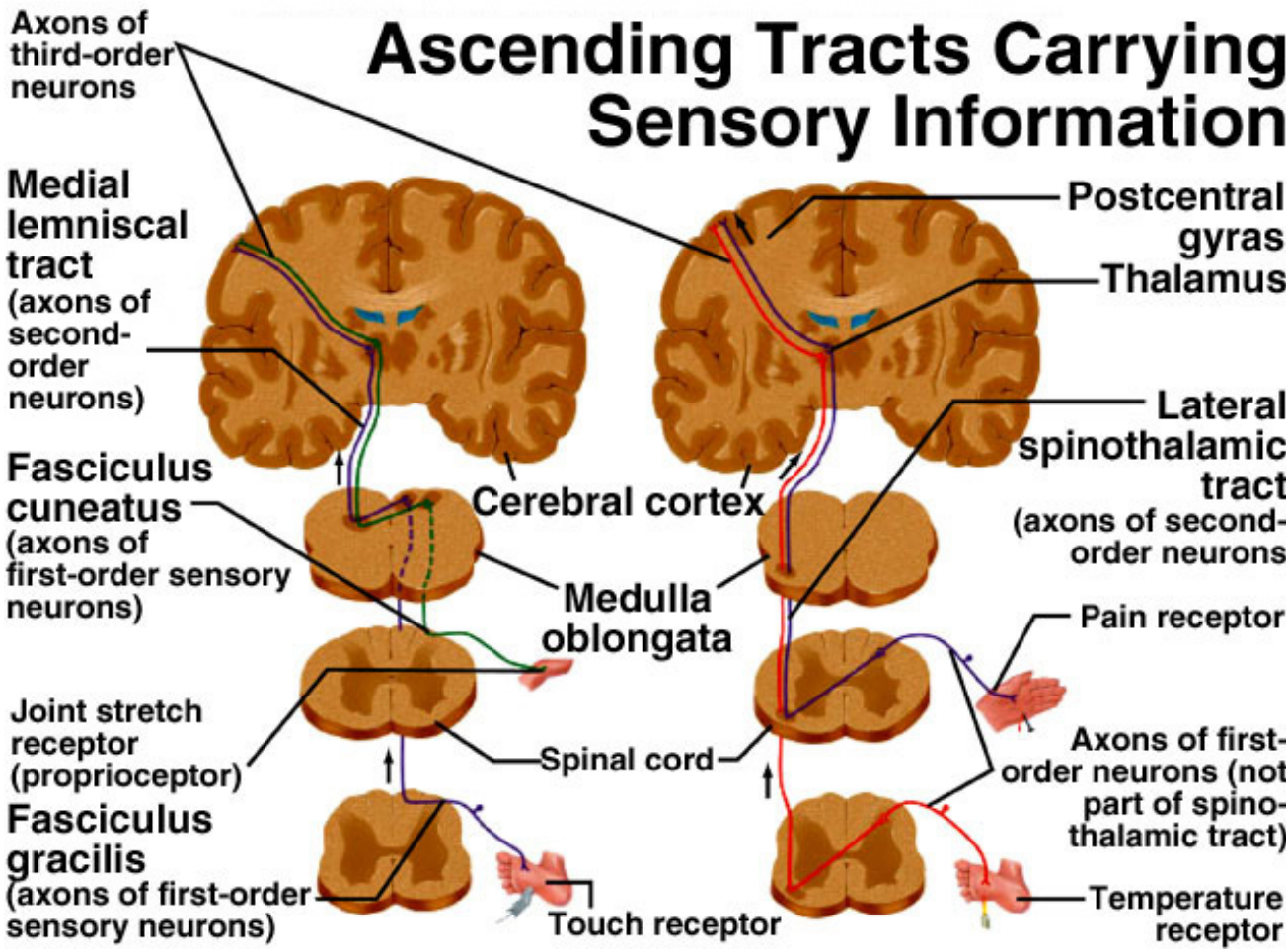


Figure 10.14 Somatic Motor Pathways

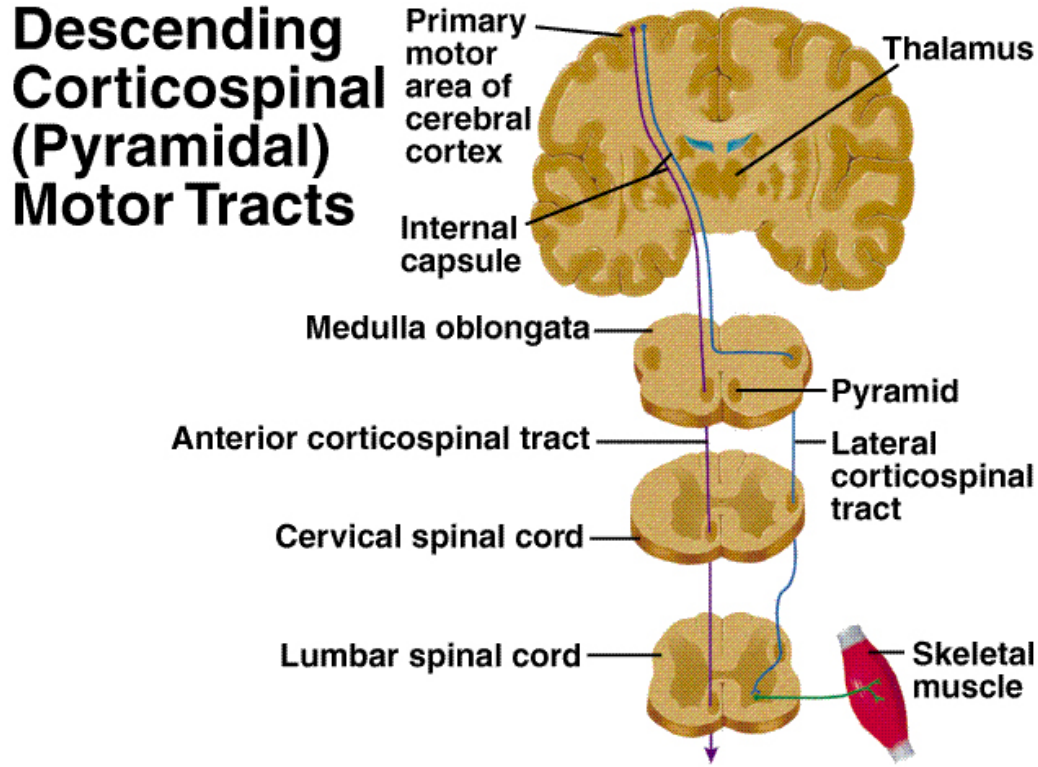
Ascending Spinal Tracts

- Convey sensory information from cutaneous receptors, proprioceptors and visceral receptors to cerebral cortex.

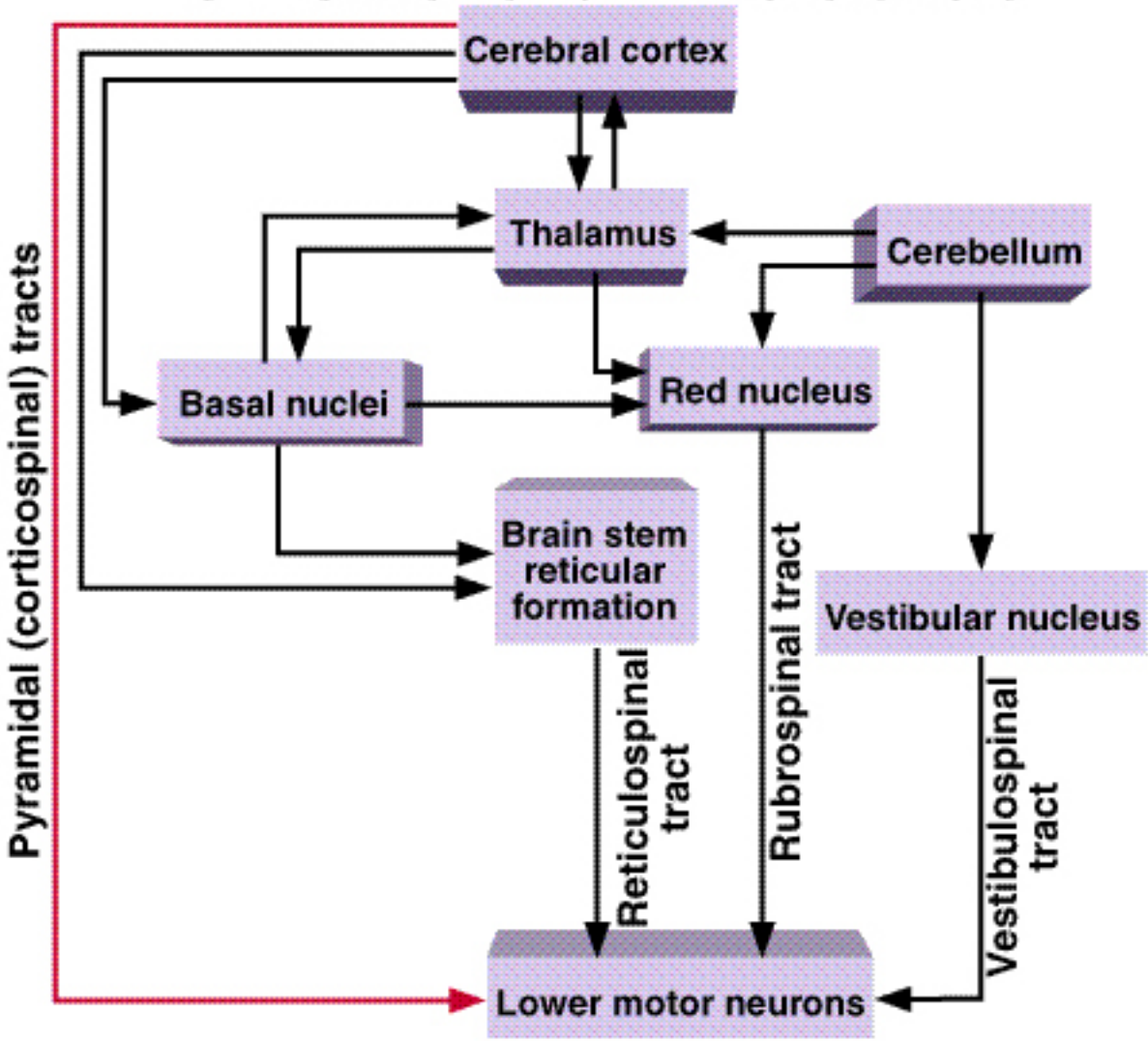

Ascending Tracts Carrying Sensory Information
Axons of third-order neurons
Medial lemniscal tract (axons of second-order neurons)
Fasciculus cuneatus (axons of first-order sensory neurons)
Joint stretch receptor (proprioceptor)
Fasciculus gracilis (axons of first-order sensory neurons)
Touch receptor
Cerebral cortex
Medulla oblongata
Spinal cord
Postcentral gyras
Thalamus
Lateral spinothalamic tract (axons of second-order neurons
Pain receptor
Axons of first-order neurons (not part of spino-thalamic tract)
Temperature receptor

Descending Spinal Tracts

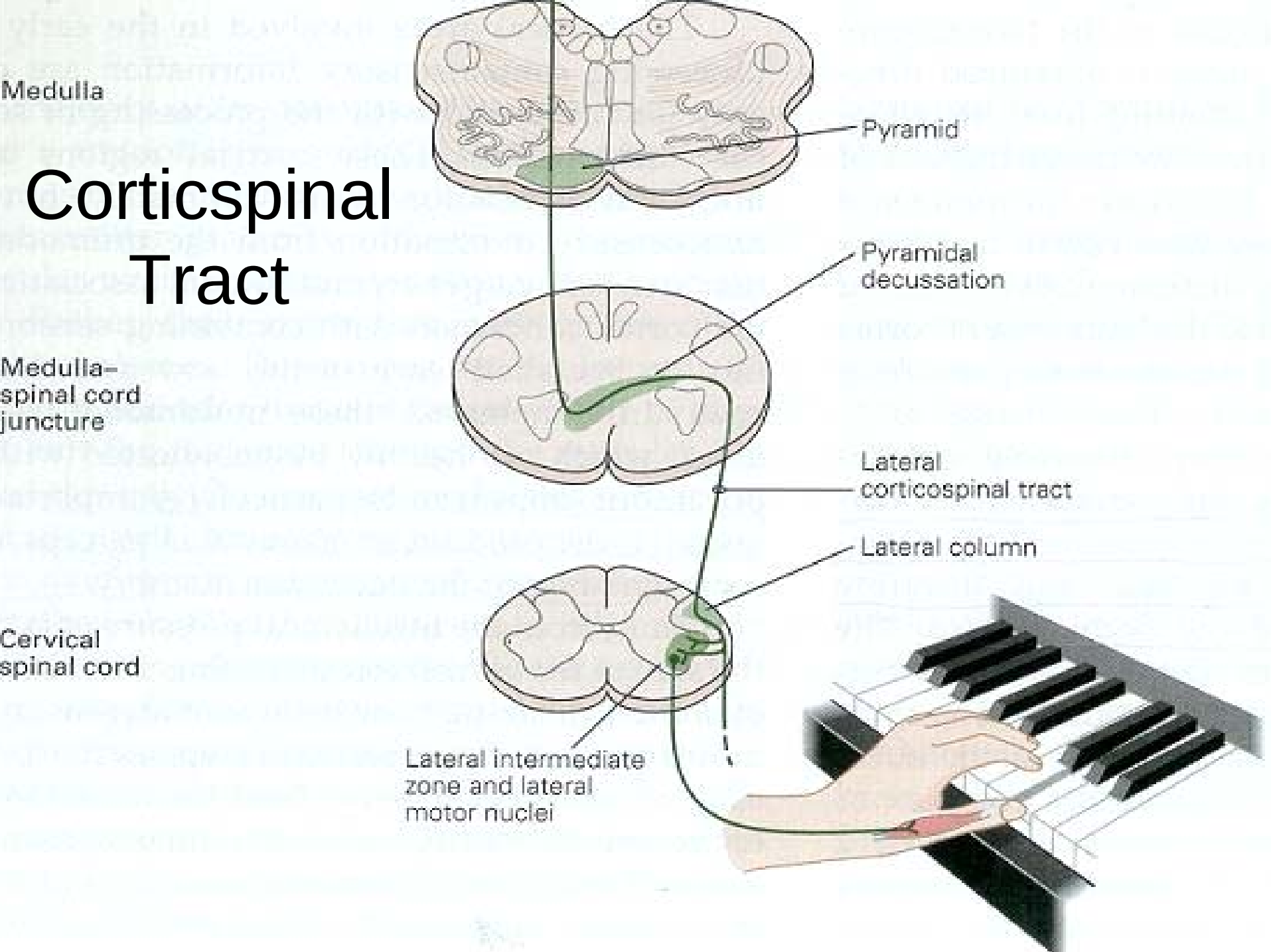
- Pyramidal tracts descend directly without synaptic interruption from cerebral cortex to spinal cord.
  - Fine movements.
- Reticulospinal tracts (extrapyramidal):
  - Gross motor movement.



Higher Motor Neuron Control of Skeletal Muscles



Corticspinal Tract



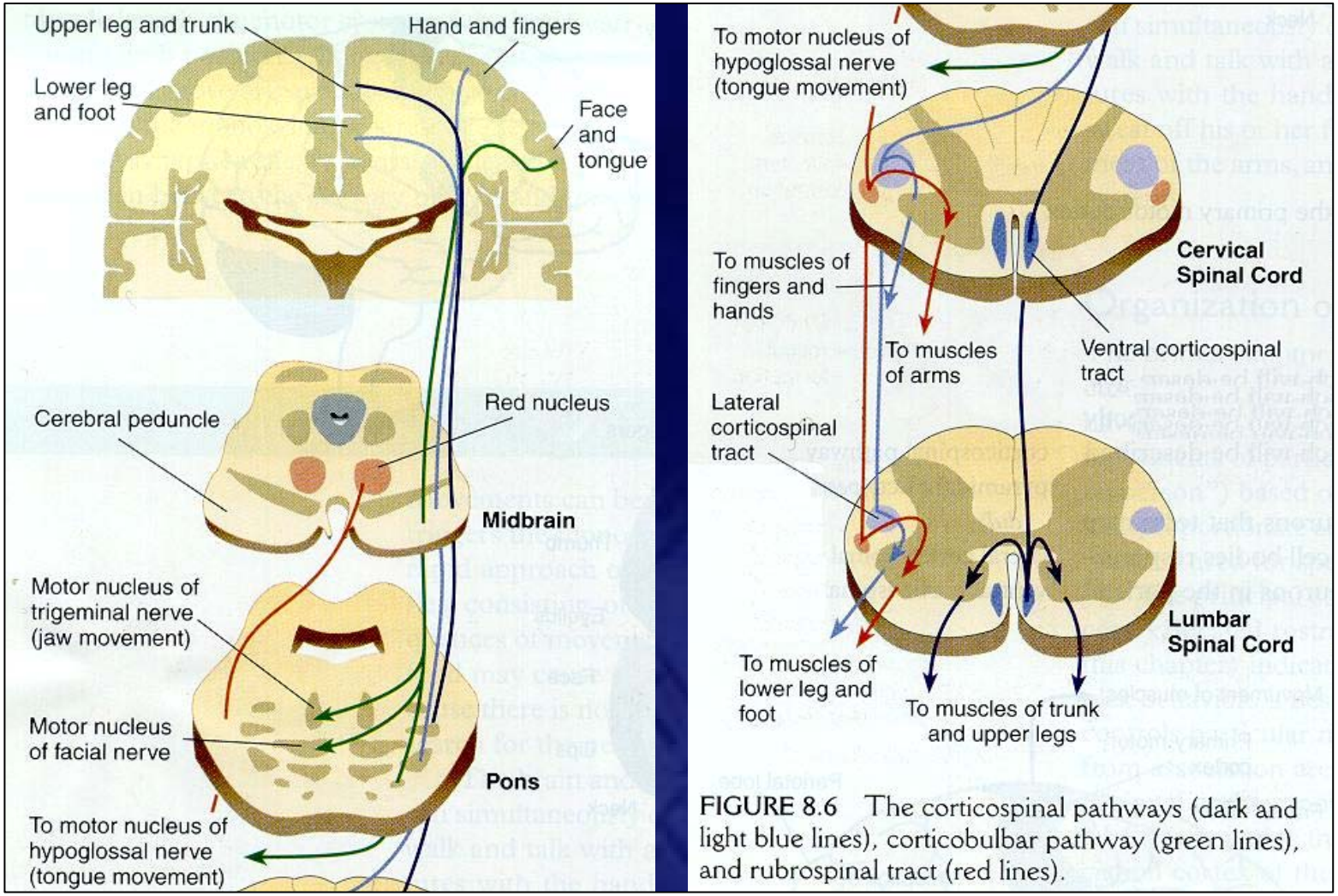

Upper leg and trunk
Hand and fingers
Lower leg and foot
Face and tongue
Cerebral peduncle
Red nucleus
Midbrain
Motor nucleus of trigeminal nerve (jaw movement)
Motor nucleus of facial nerve
Pons
To motor nucleus of hypoglossal nerve (tongue movement)
To motor nucleus of hypoglossal nerve (tongue movement)
To muscles of fingers and hands
To muscles of arms
Ventral corticospinal tract
Cervical Spinal Cord
Lateral corticospinal tract
Lumbar Spinal Cord
To muscles of lower leg and foot
To muscles of trunk and upper legs

FIGURE 8.6 The corticospinal pathways (dark and light blue lines), corticobulbar pathway (green lines), and rubrospinal tract (red lines).

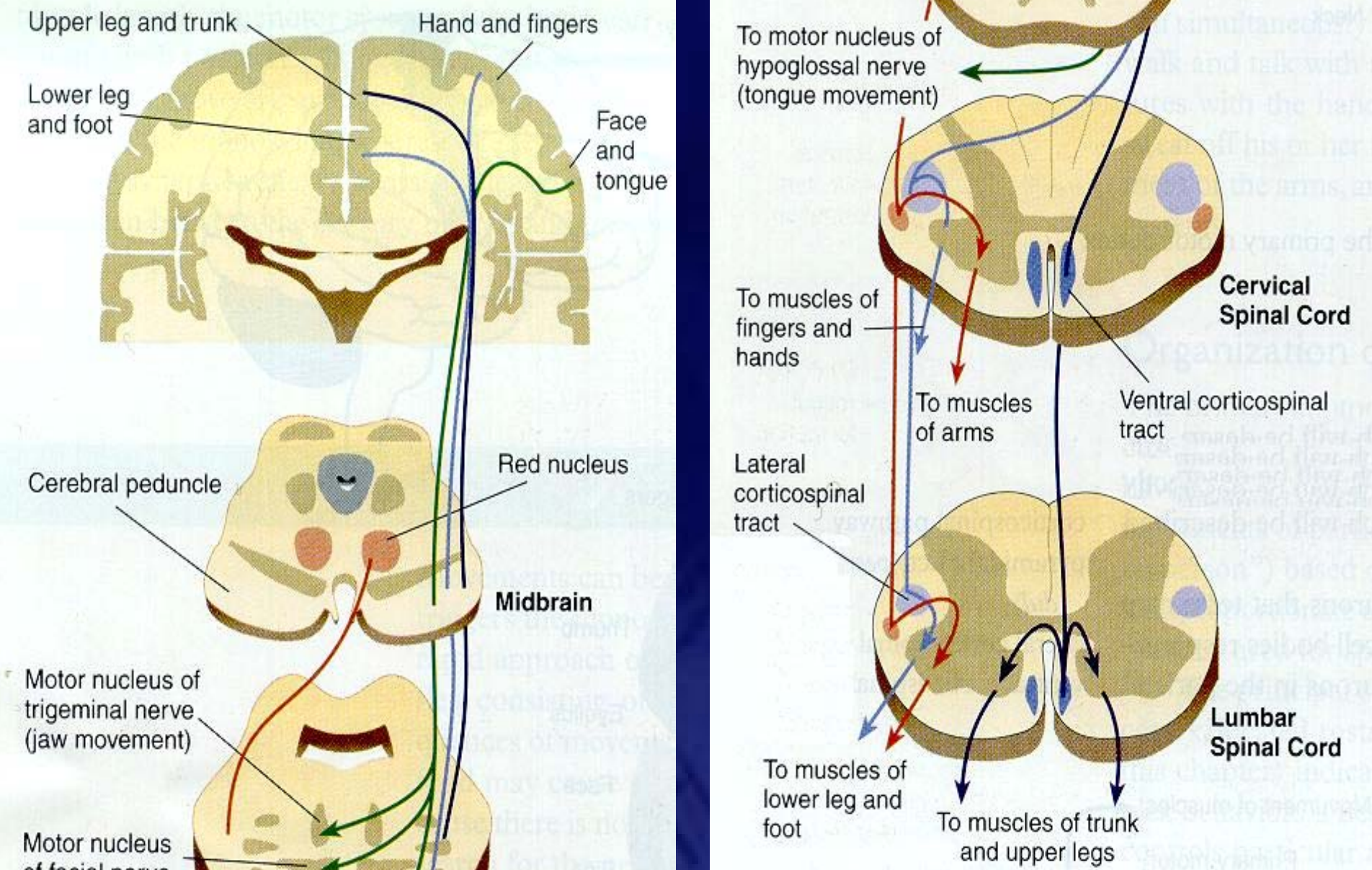

Upper leg and trunk
Hand and fingers
Lower leg and foot
Face and tongue
Cerebral peduncle
Red nucleus
Midbrain
Motor nucleus of trigeminal nerve (jaw movement)
Motor nucleus of facial nerve
Pons
To motor nucleus of hypoglossal nerve (tongue movement)
To motor nucleus of hypoglossal nerve (tongue movement)
To muscles of fingers and hands
To muscles of arms
Ventral corticospinal tract
Cervical Spinal Cord
Lateral corticospinal tract
To muscles of lower leg and foot
To muscles of trunk and upper legs
Lumbar Spinal Cord

FIGURE 8.6 The corticospinal pathways (dark and light blue lines), corticobulbar pathway (green lines), and rubrospinal tract (red lines).